Section A2
Alternative 2, Plasma Gasification/Vitrification

STARTUP AND TESTING OF THE PLASMA HEARTH PROCESS
FULL-SCALE PILOT PLANT

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ABSTRACT

SAIC's Plasma Hearth Process (PHP) is a high-temperature melter specifically designed for the treatment of low-level and transuranic mixed wastes (wastes that contains both radionuclides and chemically hazardous compounds). The design is focused on treatment of whole drums, high integrity containment of radionuclides, complete destruction of hazardous organic compounds, and state-of-the-art offgas treatment. The PHP can treat a range of wastes such as metals, soils, non-combustible inorganic sludges, combustible organic sludges, paper, plastic, rubber, and mixtures of these materials. Over the past several years, SAIC has completed numerous tests on both a 120 kW and a 1,200 kW system using a variety of surrogate waste materials. During 1995 and 1996, the Department of Energy Office of Science and Technology funded SAIC and Retech (A Division of M4 Environmental Technologies) to design and construct a full-scale (1,200 kW) PHP pilot plant.

The PHP pilot plant is designed to process whole 55-gallon drums of surrogate waste materials at a rate of 500 kg/hr. Waste drums are placed in an air lock and transferred into the feed chamber. The waste drums are then slowly pushed into the plasma chamber and drip melted into a static hearth. In the plasma chamber, a transferred arc plasma torch (operating on nitrogen at 1,200 kW) melts the waste metals, metal oxides, and metal drums, and volatilizes, pyrolizes, and partially oxidizes the organic materials. The molten metals form a layer in the bottom of the hearth and the metal oxides form a molten layer of slag on top of the metal. Feeding is interrupted and the hearth is tilted on an intermittent basis to remove the molten metal and slag. The gases released from the volatilization of the organic waste are transported into a secondary chamber and fully oxidized with excess air at 1800 °F. After exiting the secondary chamber, the gases are treated in an air pollution control system to remove course particulate, fine particulate, and acid gases.

The system startup and initial testing proved the operability of the feed system, the slag removal system, the automatic process control system, and the air pollution control system. Several tests demonstrated the continuous processing ability of the PHP system. In these tests a 55-gallon drum was processed, slag was poured, and then the process was repeated. Plasma torch operation during a single test was limited to 10 hours. The stack emissions indicated excellent combustion quality with carbon monoxide levels below 5 ppmv. As expected, the nitrogen oxide levels were high (600 to 2,000 ppmv) but were within regulatory limits. Some tests indicated the possibility of reducing these emissions to less than 200 ppmv. Particulate carryover from the primary chamber was lower than observed with the development system. This indicates that the gas flow circulation in the primary chamber was successfully improved. Particulate measurements at the stack were within regulatory limits, but inconsistent and will require additional monitoring. This paper describes the PHP process, the pilot plant design, and the results of the process startup and initial testing.

INTRODUCTION

The Plasma Hearth Process (PHP) is a high temperature vitrification technology with the potential to treat a wide range of wastes. Because of its versatility, this technology is recognized as one of the more promising solutions to the Department of Energy's (DOE's) mixed waste treatment needs. The PHP technology is applicable to the treatment of a wide range of waste types being generated and stored throughout the DOE complex, including sites such as the Idaho National Engineering Laboratory (INEL), the Savannah River Laboratory (SRL), the Hanford Reservation, and the Oak Ridge Reservation.

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The ultimate goal of this project is to prove the feasibility of the PHP technology for treating actual DOE mixed waste. In order to prove this feasibility it is necessary to demonstrate that the technology is both functional and cost effective. Functionality covers such aspects as the ability to process various DOE waste materials, control radionuclides, and meet expected environmental regulations (primarily air emissions and final waste form properties). Cost effectiveness is specific to a given project but requires a comprehensive understanding of the capital costs, operation and maintenance costs, and production rate. In order to study these various issues, three PHP systems have been constructed. One system, the primary subject of this paper, is a full-scale nonradioactive pilot plant PHP system. The other two units are both bench-scale systems. One system has been designed for studying radionuclide partitioning and the other for supporting a wide range of nonradioactive testing. The former unit is referred to as the radioactive bench-scale (RBS) PHP system and the latter unit is referred to as the STAR Center PHP system.

This document describes the pilot plant project objectives, the PHP system, the results of the operability testing, air pollution control system (APCS) performance testing, the environmental performance during startup testing, and the plans for future testing.

OBJECTIVES

The goal of the PHP pilot plant project is to advance the development of the PHP technology from batch operation to continuous operation under "production-like" conditions and to measure the system performance under these conditions. In order to achieve this goal, the following five activities are being pursued:
- Demonstrate the performance of the pilot plant engineering concepts,
- Demonstrate long-term operation under "production-like" conditions,
- Measure the parameters that are required to determine the life cycle cost,
- Determine surrogate radionuclide behavior, and
- Demonstrate environmental performance for nonradioactive parameters.

The startup testing of the pilot plant consisted primarily of the first activity - demonstrating the performance of the pilot plant engineering concepts. The objectives for the startup were to demonstrate the basic functional operation of the plasma torch and PHP melter system; evaluate the functionality of the feed system, melter system, slag removal system, and air pollution control system; and to measure the stack emissions of carbon monoxide (CO), nitrogen oxides (NO_x), and particulate.

SYSTEM DESCRIPTION

The PHP pilot plant melter system consists of a waste feed system, plasma chamber, plasma torch and mount assembly, hearth, hearth spool section, melt collection chamber, and secondary chamber. Figure 1 presents a flow sheet of the process which is described in detail in the following paragraphs.

The feed chamber is designed to hold up to three (3) 55-gallon drums of waste materials. The drums are loaded horizontally into an air lock, transferred into the feeder, and pushed axially towards the plasma chamber where they are processed in a slow, controlled manner. The plasma chamber is the section of the melter assembly where the feed system, torch system, and hearth section converge. The plasma chamber is defined as that section of the melter from the top of the hearth upward to its sealed lid. The plasma torch assembly penetrates the lid and is oriented downward toward the hearth section. The plasma chamber is water cooled to provide safe external temperatures and to limit the thermal expansion of the chamber walls such that positive seals and sub-atmospheric pressures can be maintained.

The plasma torch used in the pilot-scale unit is a Retech model RP-600T transferred arc torch with a nominal power output of 1.2 MW. The torch is water cooled and utilizes nitrogen as the primary plasma gas. Helium and argon are used in combination with nitrogen for torch startup and optimization. During normal operation, the torch arc is transferred from the torch electrode to the molten bath, where the current travels through the molten pool to a

[Place Figure 1 Here]

ground potential termination integrated into the hearth. As the plasma torch melts the drum contents, the hearth collects the molten material and contains it to allow further plasma processing. The hearth is completely contained within the hearth spool section. The design of the hearth is such that removal of the molten slag is accomplished by tilting the entire hearth one direction to remove the slag, and the opposite direction to pour the metal.

The melt collection chamber is a sealed rectangular chamber located directly below the hearth spool section. During operation, two separate collection vessels are positioned in the melt collection chamber. These vessels are set within removable, water-cooled steel shells to remove heat from the molten materials.

The secondary chamber is a cylindrical, refractory lined chamber with one end plate fitted with a 1.44 MMBtu/hr natural gas burner. The chamber is designed for a gas residence of 2 seconds at a gas flow rate of 2,400 scfm. Process offgas from the primary chamber and combustion air are introduced tangentially into the secondary chamber near the burner end. Excess air is utilized to ensure complete destruction of organic compounds in the offgas providing a destruction removal efficiency (DRE) greater than 99.99%.

The temperature of the offgas leaving the secondary chamber is reduced from 1800°F to 400°F in an evaporative cooler. The evaporative cooler injects a water spray concurrently with the flow of hot offgas. Rapidly cooling the offgas reduces the formation of dioxins and furans by minimizing the offgas residence time in the optimum temperature range for their formation and protects downstream filtration equipment. The baghouse system consists of two high temperature fabric-filter, pulsed-jet baghouses. The baghouses are designed to remove all particulate greater than 2 μm and greater than 97% of all particulates larger than 0.5 μm. The baghouse filters are pulse-cleaned when the pressure drop across a baghouse exceeds five inches w.c. Immediately following the baghouses is a two stage HEPA filter. The first filtration stage consists of a prefilter, and the second stage a HEPA filter. The prefilter removes intermediate particulate and protects the HEPA filter. The high temperature HEPA filter has a rated collection efficiency of 99.97% for particulates 0.3 μm and larger. Following the HEPA filter bank is an integrated wet scrubber consisting of a quencher and a packed bed scrubber, both utilizing a caustic scrub liquor. The quencher is designed to saturate the offgas in preparation for acid gas absorption in the packed bed scrubber. After exiting the quencher, the saturated gases enter the packed bed scrubber. This scrubber contains randomly packed internals for enhanced mass transfer during countercurrent flow of the gases and scrubber liquor. The liquor is distributed over the top of the bed using a spray nozzle system. A mist eliminator is located after the packed-bed region to remove any entrained liquor droplets or mists from the offgas stream. Scrubber blowdown is produced when the conductivity in the scrubber liquor exceeds the acceptable level. An offgas reheater is placed before the induced draft induced draft (ID) fan to raise the saturated offgas above its dewpoint. This is to ensure that no water droplets enter or form in the fan, to eliminate any corrosion problems associated with condensation in the ducting and stack, and to avoid exceeding opacity limits at the stack. Finally, the ID fan draws the offgas through the system and maintains a vacuum within the entire process.

The continuous emission monitors (CEMs) used for all NPS tests consisted of a sampling system and meters for CO, CO_2, O_2, and NO_x at the stack. These are used in conjunction with a sampling system and meters for CO, NO_x, and O_2 at the exit of the secondary chamber. Prior to testing, all CEMs were calibrated according to manufacturers specifications.

The control console for the PHP is a remotely located control center housing the main PLC interface, the personal computer based torch patterning system, the data acquisition system (DAS), and four video monitors. The video monitors are key components for the safe and efficient operation of the PHP. The cameras are positioned to provide views of the feeder, the slag pour spout, the metal pour spout, and the melt pool. Two additional cameras are positioned to view across the melt pool and to view the feed region.

The pilot-scale PHP utilizes a centralized computer control system and has few local controllers. The main computer handling the majority of the control activities is an Allen Bradley PLC-5. The PLC handles all of the control functions except those specifically related to the torch control and patterning system, which is handled by a dedicated personal computer.

TEST OPERATIONS

The test operations were designed to carefully extend the operating envelope of the system in a logical progression of increasing complexity. The first group of tests (Series A) processed drums containing broken glass, soil, and metal. The second group of tests (Series B) processed similar drums with increasing amounts of combustible material (mostly wood). The third group of tests (Series C) processed drums containing soil, metal, and various amounts of PVC plastic.

The same general testing procedure was used for all tests on the PHP pilot plant system. First, the system is preheated using natural gas burners that fire into the primary and secondary chambers. After approximately 12 hours of heating with the burners, the primary chamber burner is turned off and the plasma torch is started. The plasma torch is operated at a moderate power level to melt metal precharged to the hearth. The torch is cycled through a series of circular patterns until a fully molten pool is established. This requires two to five hours depending on the initial starting conditions of the primary chamber. At this point the primary chamber will have reached its minimum operating temperature of 1500°F, and the secondary chamber will have reached its minimum operating temperature of 1800°F. After the preheat is completed and the system has reached the minimum operating temperatures, drum feeding is initiated.

The following three sections present the results of the testing. The results are presented by classes of objectives - those pertaining to system operability, APCS performance, and environmental performance.

SYSTEM OPERABILITY

There were several test objectives specified for determining system operability. These included demonstrating continuous feeding of drums, continuous processing, operability of the slag and metal removal system, and implementation of automatic process control. The following sections present the results of the testing relative to these objectives.

Continuous Feeding of Drums
Initially several problems were encountered with the drum feed system. A non-standard 55-gallon drum, slightly taller and tapered, jammed in the feeder during the second test. This taper caused the feed drum to rotate ~90° and caused the push plate to shear from the ram rod, plugging the feed chamber. The use of these non-standard drums was discontinued. It was also found that the retaining ring (chime) that clamps the lid to the drum also interfered with the feeding mechanism. This ring was removed and the drum lids were tack welded in place until the feeder could be modified. With these restrictions, drums were routinely fed to the Pilot-Scale PHP system. The drums were fed at rates varying from 0.5 inches per minute to several inches per second.

After these tests, the feeder was modified by welding an additional steel guide plate into the feeder. This allowed the use of standard 55-gallon steel drums with the retaining ring in place. Following these modifications, drums with rings were routinely fed and processed in the PHP system. Continuous feeding of standard 55-gallon drums was demonstrated and an adjustable, controlled feed rate was also demonstrated. These modifications should also allow the use of non-standard, tapered drums, however this has not been tested.

Continuous Processing
Several tests demonstrated the continuous processing ability of the PHP system. Test B-3 was the first test to demonstrate processing of a 55-gallon feed drum, followed by slag pouring, followed by resumed processing of feed materials. Test B-6 provided a good demonstration of continuous processing. In this test, after preheating the system, a 55-gallon drum was processed, the slag poured, and a second 55-gallon drum processed. The slag produced from processing the second drum was poured, followed by a controlled shutdown. Test B-8 provided another demonstration of continuous processing. In this test, a 55-gallon drum was processed, followed by slag pouring. Two more 55-gallon drums were processed and poured. This was followed by processing two more 55-gallon drums and pouring for a third time. The test ended with a controlled shut down. Thus, the ability to intermittently pour slag while continuing operation was demonstrated.

Slag Removal System

Several tests demonstrated the functionality of the slag removal system. The system was partially demonstrated in tests B-3, B-4, and B-5. During these tests, the hearth was tilted and slag was poured into the slag collection vessel. The system was fully demonstrated during B-6. During this test, the hearth was lowered and tilted and slag was poured into the slag collection vessel. After one hour of cooling, the filled slag collection vessel was removed and replaced with an empty container. A 55-gallon drum of material was processed during the slag cooling period. Slag from processing this drum was poured into a second slag collection vessel.

Metal Removal System

After tests B-1 and B-2, it was apparent that a very long run would be required for the hearth to achieve a steady operating temperature. Without this, it was unlikely that metal pouring would be possible. The tests discussed in this report had torch operating times of 2.3 to 10.6 hours. Since the other test objectives had much higher priority it was decided to postpone testing the metal pouring system until it was possible to run for longer time periods (a minimum of 12 hours of torch time).

Automatic Process Control

The Programmable Logic Controller (PLC) was used to provide automatic control of three process variables. The controlled variables were the EC exit temperature, the PC pressure, and the SC exit oxygen concentration. The corresponding manipulated variables were the EC water flow rate, the offgas pressure control damper, and the SC combustion air flow rate. Each of the three process variables was controlled by using a separate proportional-integral-derivative (PID) control loop within the PLC. Each of the three control loops was a simple, independent, feedback control loop with one controlled variable and one manipulated variable.

APCS EQUIPMENT PERFORMANCE

There were several objectives specified for determining the APCS performance. These included operability of the secondary combustion chamber, evaporative cooler, baghouse filter, HEPA filter, packed-bed scrubber, offgas reheater, and induced draft fan. The following sections present the results of the testing relative to these objectives.

Secondary Combustion Chamber Operability

Combustion efficiency provides a simple, quantitative measure of the performance of the secondary combustion chamber. The average combustion efficiency for the APCS performance test was >99.999%, showing excellent combustion throughout the NPS process. This was due to the exceptionally low carbon monoxide levels; the carbon monoxide levels were essentially constant at 5 ppmv (corrected to 7% oxygen) throughout the tests. This compares to a regulatory limit of 100 ppm.

Evaporative Cooler Operability

The evaporative cooler operated within the design specifications, however two problems were encountered. First, the available plant water pressure of 70 psig was less than the design pressure of 100 psig. This resulted in less atomization, larger droplets, and incomplete evaporation during some portions of startup and operation. Second, the water flow control valve operation was impaired by dirt and particulate in the water. These problems were corrected after completion of the startup testing.

Baghouse Filter Operability

The baghouse filter operated in an efficient manner as per the manufacturers specifications. At the beginning of each test series the pressure drop across the filters was very small (<0.5 inches of water column) and increased very slowly throughout each test series. The maximum observed pressure drop across the baghouse filters was 3 inches of water column.

HEPA Filter Operability

Throughout all phases of testing the HEPA filter operated in an efficient manner as per the manufacturers specifications. During test operations a small pressure drop was observed across the pre-filters and across the HEPA filters. This pressure drop did not significantly change during the course of testing. The pressure drop

across the pre-filters was less than 0.3 inches water column and the pressure drop across the HEPA filters was less than 0.5 inches water column.

Packed-Bed Scrubber Operability
The packed bed scrubber operated as designed. The scrubber operated without channeling or flooding. The pH control is maintained by an automatic feedback control that turns on the caustic supply pump for 10 seconds and then waits 20 seconds for the pH meter to stabilize. The scrubber liquor conductivity is maintained below 10% of saturation to prevent salt formation in the quench section.

Offgas Reheater Operability
The offgas reheater operated in an efficient manner as per the manufacturers specifications. During testing the reheater routinely provided an increase in offgas temperature of up to 40 °F.

Induced Draft Fan Operability
The induced draft fan operated per the design specifications and provided 8 inches water column vacuum in the primary chamber during high flow conditions.

ENVIRONMENTAL PERFORMANCE

There were several objectives specified for determining the environmental performance. These included measuring particulate carryover, acid gas removal, and stack emissions of CO, NO_x, and particulate. These measurements were made by a certified sampling subcontractor according to EPA approved methods. The stack gas emissions were also monitored by onsite equipment. The following sections present the results of the testing relative to these objectives.

Flyash Mass
The total flyash collected in the baghouse provides a good estimate of the particulate carryover from the treatment process. The total flyash collected during the test Series A and Series B was less than 1% of the total quantity of material fed. This is significantly lower than the quantities observed in the previous tests. Tests conducted on the PHP Demonstration Unit typically produced two to four kilograms of flyash for every 100 kilograms of feed material. Surprisingly, this generation rate appeared to be insensitive to the feed material composition. Testing on the pilot plant system has not been sufficient to determine the rate of flyash generation from different feed materials. However, the significantly lower overall generation rate indicates that the design changes to improve gas flow dynamics in the primary chamber were successful in reducing particulate entrainment.

Prior to Test Series C, all cells in the two chambers of the baghouses went through a manual cleaning cycle. This was repeated after the conclusion of testing. Approximately 9 kgs of flyash was collected during these tests. Particulate samples were collected using EPA Method 5 sampling trains upstream of the baghouse. Based on the quantity of particulate observed and the offgas flow rate, the total particulate emissions from the process were estimated to be 4.5 kgs. 'Both sets of data correspond well to each other as the results from sampling did not include particulate emitted during heat-up of the NPS. The total quantity of material fed during these tests was 1300 kgs which also results in a carryover of less than 1%.

Particulate Capture
Particulate matter generated and captured during the melting of the feed drums for each of the tests was collected using EPA Method 5 and corrected for 7% O_2. Table I presents a summary of the particulate. CO, and NO_x stack emissions for Test Series C. As shown in the table, the emissions for the 8% PVC feed are two orders of magnitude higher than the emissions for the 16% PVC. The removal efficiency of the baghouse is 71% for the 8%PVC and 99.9% for the 16% PVC. The poor performance of the baghouse during the 8% PVC might be explained by the fact that it was forced through an extensive cleaning cycle prior to the start of the test. Optimum operation of the baghouse requires a developed layer of particulate and capture occurs within the particulate layer - rather than on the bags. It is possible that the cleaning cycle removed the necessary layer of particulate which did not redevelop again until part of the way into the 8% PVC test. This assumption is supported by the fact that the baghouse

collection efficiency significantly exceeded design criteria for the 16% PVC test (after enough time for a new particulate layer to have been developed).

[Place Table I Here]

Data for particulate levels at other points in the system do not clarify the results. For the 8% PVC test the particulate leaving the HEPA filter was two order of magnitude lower than the particulate entering the HEPA filter. However. for the 16% PVC test the level of particulate exiting the HEPA filter were an order of magnitude higher than those entering the HEPA filter. The particulate level increased across the packed-bed scrubber for the 8% PVC test, but decreased for the 16% PVC. Given the inconsistencies within this data it is inappropriate to draw significant conclusions without further measurements.

Acid Gas Removal
Acid gas removal was measured by a certified sampling subcontractor using EPA approved methods. Table I presents a summary of emissions that were measured in the stack for the APCS tests. As expected, the packed bed scrubber provides the greatest capture of HCl with removal efficiencies of >99.8%. The less than signs (<), in the table, indicate that the measured value was below the detection limit of the instrumentation, therefore the removal efficiencies were at least this number. The scrubber demonstrated the ability to exceed the Federal requirement of 99% removal of HCl for hazardous waste incinerators. The average mass of HCl exiting the system in the exhaust stack for the 8% PVC test is less than 0.011 lb/hr and 0.012 lb/hr for the 16% PVC test. This is far less than the regulated quantity, <1.6 lb/hr of HCl emissions.

Scrubber Liquor TDS/TSS/Cl‾
The scrubber liquor had three discrete samples taken prior to the start of testing and three taken at the completion. All samples collected were analyzed for total chloride using EPA SW-846 Method 9253, EPA Method 160.1 for total dissolved solids (TDS), and EPA Method 160.2 for total suspended solids (TSS).

As expected. the total chloride level in the PBS sump increased between the tests. The pre-test chloride level was determined to be an average of three samples of 58.33 mg/L with a standard deviation of 2.36. At the completion of testing this level had risen to 4,550 mg/L (s.d. = 70.7). This data. coupled with the exhaust gas emission levels of HCl. indicates that the packed bed scrubber is very efficient in the control and capture of the acid products of combustion when using halogenated compounds in the feed drums.

Stack Gas Emissions
The stack emissions data for all tests were obtained from a permanent onsite continuous emissions monitoring system (CEMS) which monitors the stack gas for CO. CO_2. O_2, and NO_x and a separate system that monitors O_2.

CO. and NO_x at the exit of the secondary chamber. In addition to the monitors on the PHP system. a sampling subcontractor provided EPA approved monitoring during Test Series C. The results of these measurements are shown in Table I. Plots of CO and NO_x emissions for Test B-6 are shown in Figure 2. The plots show that the CO level remained below 5 ppmv. well below the regulatory limit of 100 ppmv. Combined with an average CO_2 level of 5.0%. the combustion efficiency was on the order of 99.999% (defined as $[CO_2 - CO]/CO_2$). The data collected for the 26% PVC followed closely that of the 8% PVC test. with average values of CO and CO_2 of 4 ppmv and 5.4%, respectively.

The combustion efficiency is not to be confused with the Destruction and Removal Efficiency (DRE) used when determining the thermal destruction of a principal organic hazardous compound (POHC). The combustion efficiency only provides an indication of the ability to thermally destroy hazardous organic compounds. The combustion efficiency achieved demonstrates that the process is providing extremely high quality combustion.

Figure 2 shows that the NO_x level for Test B-6 varied between 70 ppmv and 180 ppmv. These levels are very low for a plasma processing system. Significantly higher concentrations were observed in other tests. As shown in Table I, the average level of NO_x in the offgas for the 8% PVC test was 1,964 ppmv. This NO_x concentration, combined with an average flow rate of 850 dscfm. leads to an emission rate of 8.06 lb/hour, below the pilot plant regulatory limit of 18.4 lb/hr. The NO_x emission rates, corrected to 7% O_2, for the 16% and 26% PVC tests were 788 ppmv and 626 ppmv respectively. These NO_x emissions levels are good, considering that the PHP is a high temperature process using nitrogen as the torch gas in the presence of air and without including any NO_x abatement. There are at least two factors that explain the reduction in NO_x between the different sets of tests. The first is that the primary chamber combustion air was split 50/50 between the upper portion of the chamber and the lower feed/torch zone during the 8% PVC test. Prior to feeding the 16% and 26% PVC drums this combustion air split was changed to 75% entering the upper portion of the chamber and only 25% in the lower feed/torch zone. This resulted in a less oxygen in the hot plasma region to form the NO_x. The second factor is that the increase in the quantity of hydrocarbons (from 8% PVC to 16% and 26%) resulted in a more reducing atmosphere - which prevented the formation of NO_x.

[Place Figure 2 Here]

FUTURE TESTING PLANS

After completion of the startup tests, the PHP pilot plant system was shut down for maintenance, repairs, and system upgrades. The only major change to the melter system was to modify the feeder isolation door to improve sealing. The only major change to the APCS was to add a booster pump to the evaporative cooler water supply. The process control system, primarily the PLC operator interface software, was extensively modified to correct problems and deficiencies observed during startup testing. This operator interface is easily changed to accommodate system upgrades or operator preferences.

Beginning in April of 1997, the system will be restarted and several shakedown tests will be conducted to evaluate the operability of the modifications. After the restart, testing will proceed with several long tests - 100 hours of plasma torch operation per test. During these tests, data will be collected to evaluate plasma torch life, to complete a life cycle cost model, to measure process performance, to measure control and containment of radionuclides, and to measure the process environmental performance.
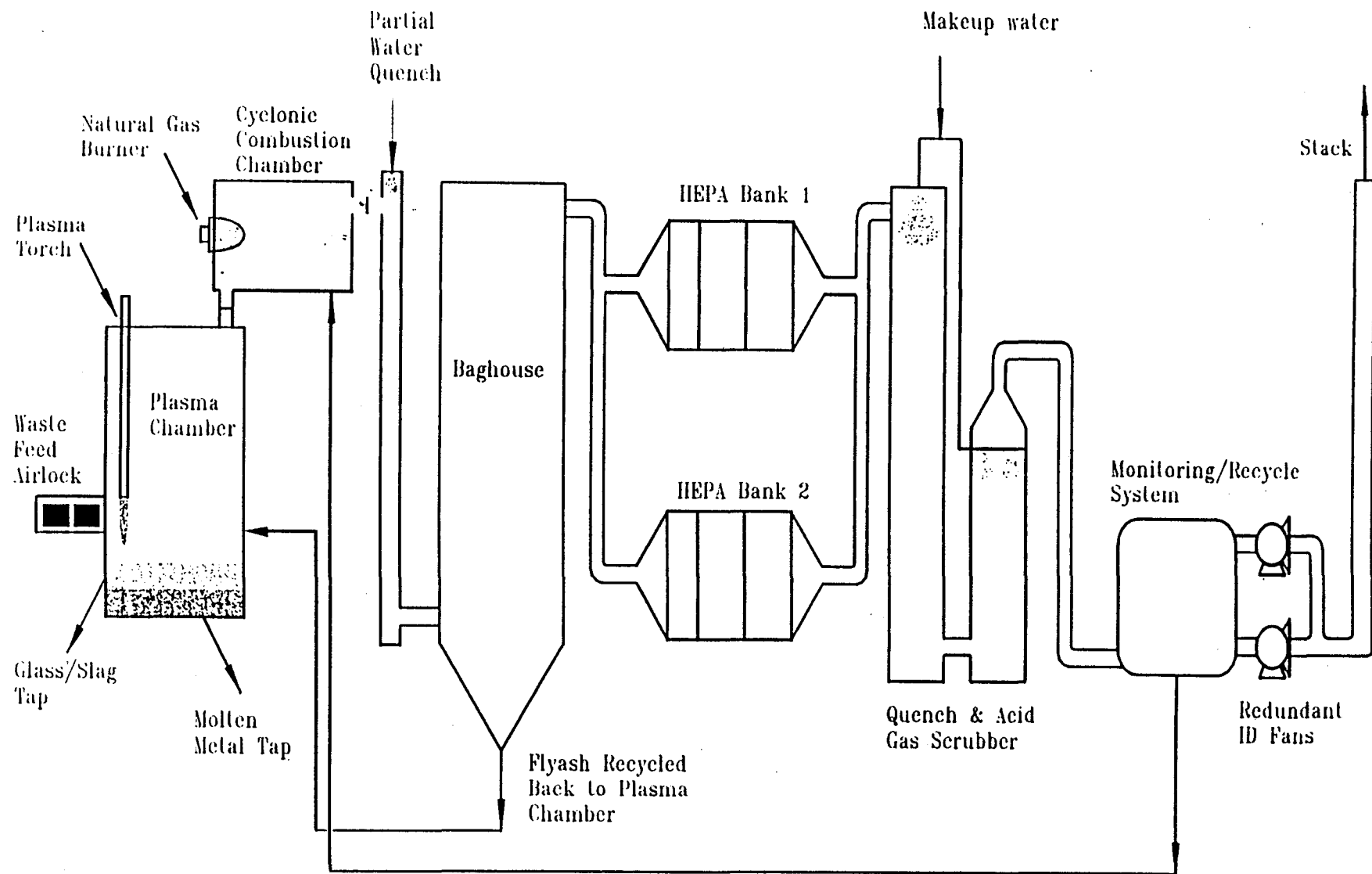
Figure 1. Process Flow Sheet for the Plasma Hearth Process

Table I. Comparison Between Actual, Project Objectives, and Regulatory Offgas Emission Levels.

		HCl	CO	NO$_x$	Particulates
Actual Emissions	8% PVC	<0.011 lb/hr	0.01 lb/hr 6 ppm	8.06 lb/hr 1,964 ppm	0.14 lb/hr 0.029 gr/dscf
	16% PVC	<0.012 lb/hr	0.02 lb/hr 6 ppm	3.32 lb/hr 788 ppm	<0.0042 lb/hr <0.00079 gr/dscf
	26% PVC	NA	0.01 lb/hr 4 ppm	2.82 lb/hr 626 ppm	NA
Project Objectives		<1.6 lb/hr	<100 ppm	<3,500 ppm	<0.015 gr/dscf
Regulatory Emissions		<1.6 lb/hr	<0.6 lb/hr	<18.4 lb/hr	<0.18 lb/hr

Figure 2. Stack Emissions of Carbon Monoxide and Nitrogen Oxide for Test B-6.
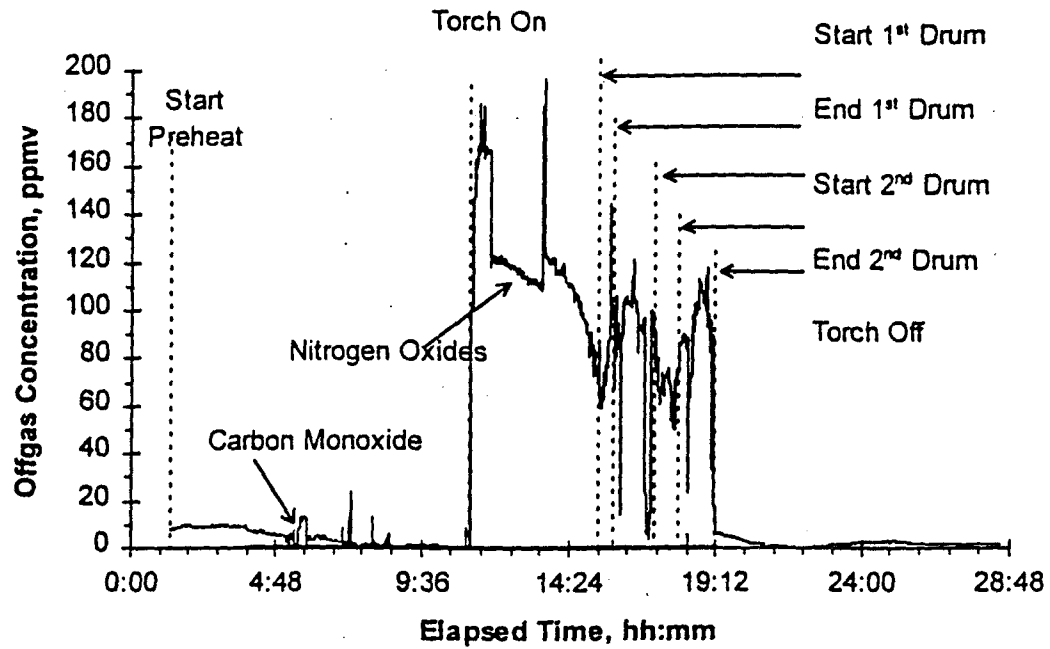
PLASMA ARC MELTING TREATMENT PROCESS OF LOW LEVEL DRY ACTIVE WASTE

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ABSTRACT

The Japan Atomic Power Company (JAPC) and Toyo Engineering Corporation (TEC) have developed an incinerating/melting process using the Plasma Arc Centrifugal Treatment process (PACT) for Low Level Dry Active (Miscellaneous Solid) Waste (DAW). We had supported tests of melting incombustible waste, tests treating organics which have high chlorine/sulfur content with controlling, together with incombustible waste, and tests of certifying the proper characteristics of solidified slag and metal.

JAPC placed an order with TEC for constructing an incinerating/melting facility using Plasma Arc Centrifugal Treatment process (PACT developed by Retech ,USA) in Tsuruga Nuclear Power Station because of it's advantage in progress of development and the highest treatment effeciency at the result of comparison with other plasma technologies in 1995. This paper shows the results of incineration/melting tests and explains the concept of our Plasma Arc Waste Volume Reduction Facility, for which engineering is on-going.

INTRODUCTION

In Japan, Nuclear Power Stations have begun to transport for a shallow land disposal to Low Level Radioactive Waste Disposal Center (Rokkasyo, Aomori) since December, 1992. In the first phase operation of the Center, the target waste is the solidified liquid waste, but they are planning to start the disposal of DAW consist of concrete, insulation materials, filters and metal wastes in the second phase from around 2000.

Japan is evaluating some specified ways in DAW treatment for final disposal. One is the mortar filling solidification process which pours mortar into 55gal drum containing pre-placed wastes. This process needs to sort the wastes according to the shape and the strength and to remove Aluminum, Combustible Materials etc. from wastes in advance of solidification for the purpose of the stable waste form. Another is an incineration /melting process which has the advantage of reducing the pretreatment work removing them.

JAPC selected the latter one: incineration/melting and chose a Plasma Arc Melting technology as the treatment process to minimize the overall cost of treatment and disposal, to reduce those volume and to convert wastes to a stable waste form. In addition, the Plasma Arc Melting technology has a large treatment capacity and has a capability of processing a variety of wastes including organics in a single step.

Plasma Arc Melting technology , however, was not established as a treatment process for DAW in Japan except municipal waste incineration ash melting. Then JAPC planned to carry out some certification tests to show whether plasma technology is suitable for radioactive waste treatment or not.

CERTIFICATION TEST
Purpose of Test

We performed the test according to the waste component of Table I
Place TABLE I here

Tsuruga Station wastes include PVC and Rubbers and we want to treat those organics in mixture with other inorganic and metal wastes. Some plasma scientist believed that when treating organic waste, plasma arc may be cut off because decomposed organic gas would disturb normal arc operation. If we can not treat organic waste in plasma furnace, we must prepare the other treatment technology for organics in addition to inorganic/ metal plasma melting furnace.

The behavior of the radioactive nuclides is very important for the high temperature treatment of radioactive waste because it affects the method of measurement/ evaluation of radioactive nuclides for final disposal. Especially Cesium is the key nuclide in the evaluation of β emitters and it is required to remain in the slag layer.

Test Procedure

We performed the test with PACT-2 and PACT-8 of MGC-Plasma, Muttenz, Switzerland. The PACT-2 has 2feet I.D. furnace and 150kW torch and the PCAT-8 has 8feet I.D. furnace and 1,200kW torch. We used the PACT-2 as bench scale test apparatus and the PACT-8 as performance test apparatus. Table II shows the contents for all the test run.

Place TABLE II here

-Surrogate waste:

We prepared the surrogate waste as follows.
PVC sheet, Rubber, Activated Carbon, Ion exchange resin, Concrete, Metal (stainless steel, carbon steel)

-Surrogate nuclides:

We prepared the surrogate nuclides as follows.
Co_3O_4, Cs_2CO_3

-Measurement and analysis

We analyzed the following items; off gas component (O_2, CO, CO_2, SO_2, NO, NO_2, HCl, HC, dust),slag component, Carbon and Sulfur content in the slag layer and Cs & Co content in the slag layer and metal layer.

-Bench scale test(PACT-2)

Test run No.1 - No.10 were performed with the PACT-2. We got the basic knowledge in these bench scale tests and then verifyed those condition with the PACT-8.

-Performance test(PACT-8)

Test run No. 11- No. 12 were done in the PACT-8. We prepared concrete blocks which were half the size of a 55gallon drum, and 55gallon drum filled with DAW.

Test Result

Test results showed that the Plasma Arc Melting technology could efficiently melt incombustible waste with equality heating, with metal and organic.

We discuss the following items:

-Stability of torch operation
We could operate stably the plasma torch even when we treated substantial quantities of organic.

-Sufficient incinerating/ melting capacity
We could treat organic in the capacity of 150kg/h at least and the inorganic and metal melting rate is 650kg/h at least. Remaining carbon content in the slag layer is under 0.03% and we think it certifies that the incineration is complete.

We also treated half drum size concrete block,charged into the hearth bottom.

-Design data for off gas treatment process
We got the component of CO, NOx. SOx, HCl and so on in off gas.

-Characteristics of solidified melt
We got two separated layers of solidified melt: slag is upper layer and metal is lower. The slag phase was glassy and homogeneous. Average slag specific density was about 2.6 g/cm^3.

-Behavior of nuclide
Cs remained about 50% in the slag layer even after 500 minutes melting period. Almost all the Co charge was in the metal layer. Fig. 1 shows Cs distribution ratio in slag.

Those nuclides existed homogeneously in both layers: slag and metal. Fig.2 shows the result of the slag and metal homogenity

Place Fig. 1 here
Place Fig. 2 here

-Feeding System
We verified the operability of the horizontal drum feeding system with 55gallon drum.

We are satisfied by the results of these tests and verify that the Plasma Melting technology is adequately useful for treatment of Low Level DAW.

We are planning to evaluate the balance of materials and radioactive nuclides from melting furnace to the stack and improve upon operability of plant and maintenance method by applying automation within two years.

CONTENT OF CONCEPTUAL DESIGN
Tsuruga Station has stored many Dry Active Wastes. Some special features about its station is that there are a little of many wastes: PVC, Rubber and the other organics. We have verified that PACT can adequately treat organics/inorganic waste mixture in our tests.

The conceptual flow diagram is shown in Fig.3 and we summarize the specification of Tsuruga plant in Table III.

Place TABLE III here
Place Fig. 3   here

Feeder System

We have discussed the way to feed into the furnace the following items: the weight, the shape and the size of waste, the chemical characteristics; organic, inorganic or metal and it's chlorine content and so on. We selected the following feeding system.

-Main waste feeding

We will feed the 55gal. drum into furnace with Horizontal Drum Feeder and cut the drum with drum cutting torch.

-Heavy waste feeding

Heavy waste will be filled in 4 or 5drums and settled on the bottom of hearth with Vertical Drum Feeder before starting a day operation for protecting hearth refractory.

-Continuous feeding

We are planning to feed organic waste continuously with a Screw Feeder at a constant feed rate for the purpose of reducing peaks in off gas generation.

Operation Mode

Our basic operation mode is day time operation (8hr/ day) but the plasma furnace has adequate design for 24 hr. operation. Therefore we have to prepare the storage area of feed waste and solidified waste and adjust the capacity of pretreatment operation.

Optimum Operation Condition

We are now continuing the performance test and we will be able to get the optimum operation condition.

Process Flow and Material Balance

We discussed the rational waste stream and material balance. We are now continuing to analyze the material balance and activity balance. Especially concerning with activity balance, we must get detailed data to verify that public exposure from off gas is extremely low.

Off Gas Treatment Process

In Japan, they have approximately from 25 to 30 incinerators in nuclear field. Those incinerators have almost been installed with Ceramic Filter (CF) as dry off gas treatment systems. We also decided to adopt CF as removing radioactive nuclides but we have to solve the acid gas treatment due to HCl and SOx from organic waste. We are now planning to install a caustic scrubber after removing the radioactive nuclides with CF and discharge the scrubber waste water to sea after neutralizing and monitoring.

We are now performing the decontamination factor test of the off gas treatment system with both cold tracer and R.I. tracer. We will be able to get the result in the near future.

Final Waste Form
     We have to condition waste to a final disposal form. Regulation of waste form is not yet finally decided but the following items will be required. We are planning to inspect these final wastes based on transport and disposal regulation and send them to the disposal site with steel container by ship.

     -Container vessel is 55gal. drum fitting with JIS
     -Not heavier than 1 ton/ drum
     -Solidified or filled with mortar
     -Without large vacancy inside waste form
     -Evaluation of radioactive nuclides content as follows; Co-60, Cs-137, Sr-90, I-129, C-14, H-3, Ni-59, Ni-63, Nb-94, Tc-99, Total alpha emitter
     -Removing inhibited materials such as lead etc. for disposal.
     and so on
     We can solve some of those items because we adopted the melting process but we have to take care to limit the weight for example. We must adjust the feed ratio between inorganic and metal not to excess the weight of waste form over 1 ton/ drum.

Concept of Building
     We discussed the basic equipment layout and the concept of building. Fig. 4 shows the appearance of our planned facility.

     Place Fig. 4 here

CONCLUSION
     We got good results of our certification test. Then we have started the basic design and the second phase of performance testing.
     The basic design and this performance test now going on are used for application to the approval for installation to the Regulatory Authorities and of course are used as our detail design data. We hope to apply to the Regulatory Authorities within this year and start to construct in 1998. Turn over and operation start are expected in 2001.

Table I : Component of waste for test

Waste	wt%
Metal(Carbon steel, Stainless steel)	42
Concrete, glass and Insulating material	30
Organic(PVC, Rubber, Activated Carbon)	22
Incineration Ash	4
Spent Ion Exchange Resin.	2
Total	100

Table II : Certification Test Run

Run No.	Test Apparatus	Surrogate Waste	Surrogate Nuclide	Measurement and Analysis
1	PACT-2	PVC, Activated Carbon(AC), Rubber, Ion Exchange Resin(IRE) and those mixture	-	Off gas component O_2, CO, CO_2, SO_2, NO, NO_2
2	PACT-2	Concrete and metal in can(100mmD,200mmH)	-	HI, HC, Dust load
3	PACT-2	Concrete block and metal	-	
4	PACT-2	Concrete, Metal and 10% organic(PVC etc.)	-	Operation condition
5	PACT-2	Concrete, Metal and 20% organic(PVC etc.)	-	Current, Voltage, temperature,
6	PACT-2	Concrete, Metal and 30% organic(PVC etc.)	Co, Cs	furnace inside pressure
7	PACT-2	Concrete, Metal and 20% organic(PVC etc.)	Co, Cs	
8	PACT-2	PVC, AC, Rubber,IER separately feed	-	Component of slag and metal
9	PACT-2	PVC, AC, Rubber,IER and those mixture	Co, Cs	(Run No. 6-11)
10	PACT-2	PVC, AC, Rubber,IER and those mixture	-	Residual ratio C,S and Cs,Co
11	PACT-8	Concrete, metal and 25%organic in 55gal. Drum	-	in the Slag layer.
12	PACT-8	Concrete, metal in 55gal. and 25gal.Drum	-	(Run No. 6-11)

Table III : PLASMA MELTING FURNACE GENERAL SPECIFICATION

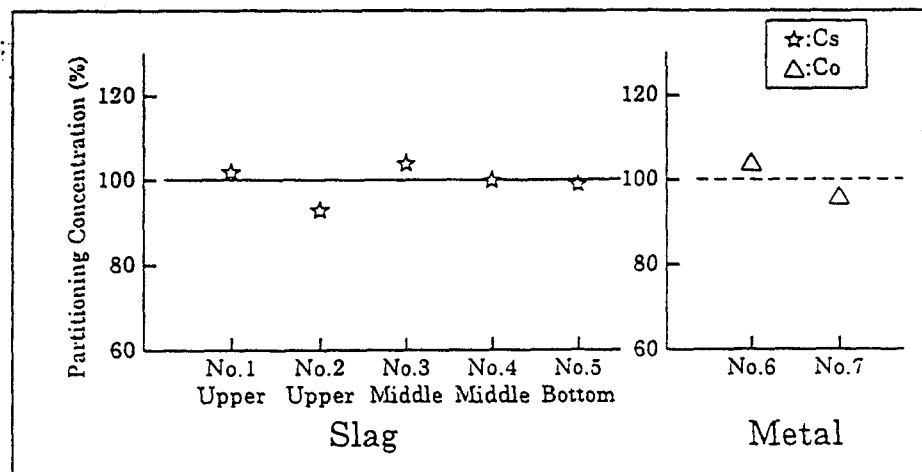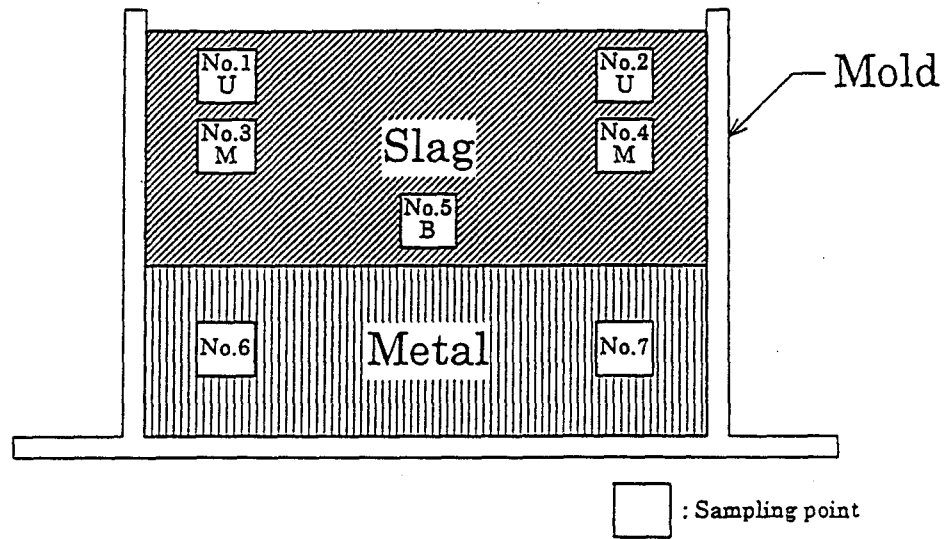| ITEM		SPECIFICATIONS
Plasma Melting Furnace		
	Type	Centrifugal Furnace
	Torch Output	1,200kW (Transferred)
	Torch Gas	Nitrogen
	Size	Centrifugal : 2.1mI.D. x 1.1mH
	Condition	Temp. : 1,500-1,600 °C (as melt)
		Rotation Speed : 40-50 round/minute
	Wastes Supply	Horizontal Feeder (Metal, Inorganic)
		Vertical Feeder (Heavy waste , Ash)
		Screw Feeder (Organic)
	Operation Time	Mon. to Fri., 8 hour/day, 200 day/year
Melted Waste		Solidified two layers of Separated metal and Slag
	Casting Mold	Thin Steel Mold
	Cooling	Cooling Air Recirculation
	Waste Form	200l DRUM (Mortar Filling)
Off-gas Treatment System		
		Ceramic Filter
		HEPA Filter
		Scrubber for HCl and SOx
		DeNOx system
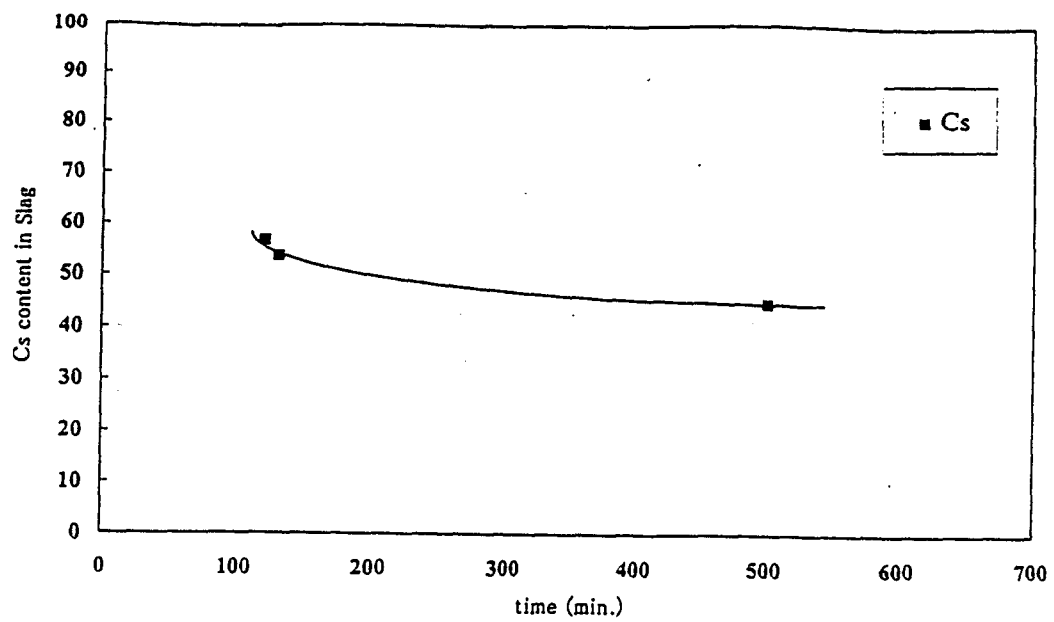
Fig. 1 Relation between Cs distrbution in the slag and operation time

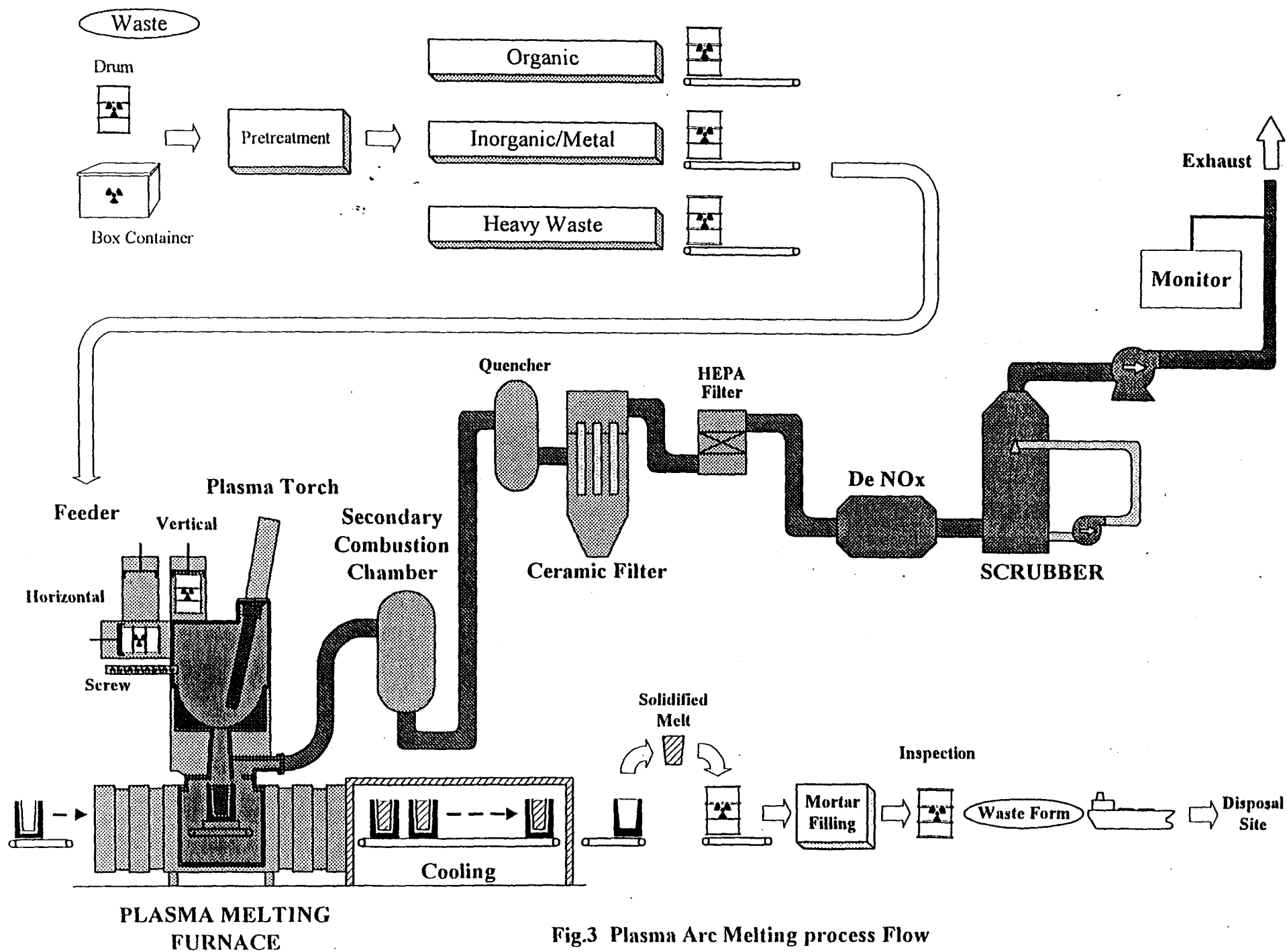Fig.3 Plasma Arc Melting process Flow

Building Structure : Reinforced Concrete
Building Size   : 2F-2BF(ab.34m×38m)
                     Height 13m from ground level
                     Underground level -13m

Plasma Melting Furnace

Ceramic Filter

2nd Off-gas Cooler

Secondary Combustion Chamber

1st Off-gas Cooler
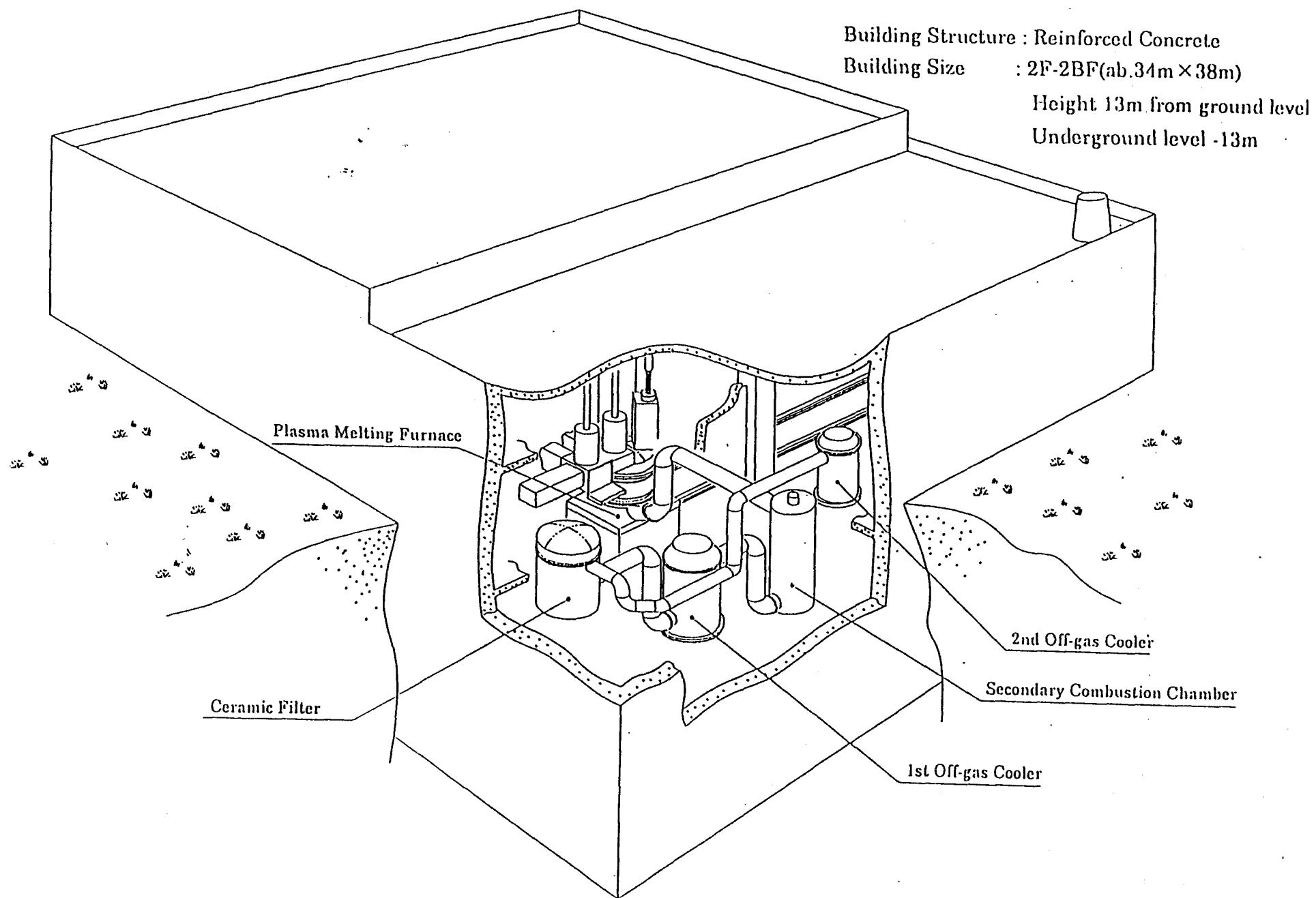
Fig.4 PLASMA MELTING FACILITY BUILDING

HARTBEAT
Hawaiian Area Rapid Transit
Beautiful Excursion Aerial Transport

IMPORTANT-MESAGE
DO-NOT-TREATLIGHTLY

THE ENERGY CONVERTER

Rubbish to electricity

Regardless of the additional load, the rail-tramway will place upon Kaua'i's electrical production additional needs, the island will still need more electricity production. Population growth, based on current projections alone,will create this need. The planners of HARTBEAT, whose philosophy is to incorporate as many problems and concerns as possible into one action, look at this and ask, "What kind of electrical generating facility would follow the tenets of this philosophy and suit the needs of a community with a need for more electricity?" As solar electric production has already been discussed, there is an additional source of energy production also to be considered.

On September 14, 1989,the County of Kaua'i conducted a seminar at the Aston Kaua'i Resort Hotel. At that time they came up with these conclusions:

County Landfills Are Filling Up. Suitable landfill sites are getting scarce. Construction and operation costs have increased dramatically. Solid Waste Production is Rising. Wastewater sludge is increasing as flows increase, new plants are coming in to operation and primary treatment plants converted to include secondary treatment capability. Commercial Users Face Increasing Disposal Costs. Tipping fees, transportation and cover material costs are being added to the normal charges.

The most obvious method of electrical production, taking these concerns as stated by the County of Kaua'i, is a *garbage converter*. The HARTBEAT planners not only support a trash to energy converter, but believe that it should include more in what it deals with. The incinerator we propose will incorporate these needs. Kaua'i's converter may:

1. Burn Garbage

2. Burn Bagasse

3. Burn Methane Gas

4. Burn Low Sulfur Coal, if required

5. Burn Automobiles and prepare them for being placed in the ocean for the establishment of artificial reefs,or shipment to steel plants on the Mainland for recycling. If so desired.

6. Treat Solid Sewage Waste and convert it into additional burning material, or use it as dry sludge to be an additive to compost to be used as fertilizer.

The need for converting garbage is obvious; diminishing landfill space is already a problem and there are projections for significant increases in Kaua'i's population which will only worsen the problem. The main criteria for burning garbage is: that it can be done so as not to allow the release of dangerous pollutants into the atmosphere. This can be accomplished with the new plasma technology.

Dioxin emissions are a particular concern because they are greater at lower temperatures, "the old incinerators".

PLASMA TECHNOLOY = ZERO EMISSION

Bagasse, a sugar by-product, could be easily incorporated into the incinerator and it would be easy to deal with the disposal of the substance. Initially, bagasse could be allowed priority because its disposal is presently being handled by plantation facilities on Kaua'i; however, the incorporation with the incinerator is preferable. A cooperation between private and a facility such as the incinerator would be necessary.It is essential to keep the boiler running at all times, (a base load power plant) for it to operate at optimum efficiency. It would be good to use low sulfur western coal to supplement. 1st Bagasse and 2nd no longer recyclable trash, and as a back-up fuel source, coal, as there may be some time periods in which the garbage may not be in sufficient enough quantity to maintain the electrical demand or keep the base load. Because a fuel such as low sulfur domestic western coal, bunker 6 would not be used. The transport of the coal could be done with the sugar boat, coal westbound, sugar eastbound. The wastewater from cleaning the boat would go to the settlement pond by the incinerator. The right-of-way of the rail line would provide for the pipeline routing. The primary purpose for a back-up fuel source is to maintain optimum efficiency of the boiler, but we do not want to use an expendable source of energy and not replace it with solar power. In the future,the HARTBEAT planners foresee the use of a garbage burning incinerator and solar power as the primary means of generating electricity on the Garden Isle.

Read the HARTBEAT design for the use and storage of methane gas byproducts.

Up to HARTBEAT index

Real World Web Productions

An Economic Development Success Story

Integrated Environmental Technologies: Plasma Process Aids Waste Treatment

Three inventors and a successful business entrepreneur have formed a powerful team to commercialize an award-winning conversion technology for treating solid wastes. Their new company, Integrated Environmental Technologies, was launched with the help of Pacific Northwest National Laboratory and the U.S. Department of Energy through an innovative program that assists local entrepreneurs and Pacific Northwest staff members who wish to start a business. This combination of entrepreneurial creativity and Pacific Northwest assistance is bringing new jobs and other economic benefits to the Mid-Columbia region.

Economic Benefits

By opening an office for their company, the entrepreneurs have already created three new jobs in the Tri-Cities. Moreover, the new technology, known as controlled plasma glassification, offers many other economic benefits. It enables effective treatment of many wastes that now pose a major environmental challenge throughout the world. It is well suited for most solid waste streams: medical, hazardous, radioactive, and mixed industrial types as well as municipal solid waste. Also, the technology is environmentally sensible. A high volume of waste can be processed in a relatively small unit in a manner that virtually eliminates the hazardous emissions associated with technologies such as incineration. Finally, it is cost effective. For example, the gas produced by the process may be utilized in a combustion process to generate electricity. The generated power is often sufficient to maintain the operation—with perhaps enough excess for resale. Thus, the energy efficiency can lead to lower operating costs.

The product of IET's controlled plasma glassification process is very durable and safe, and could be recycled for other uses, such as construction.

The glass-like product does not have secondary disposal problems associated with ash from incineration and other thermal technologies. In fact, the product is very durable and safe, and could be recycled for other uses, such as construction.

The Technology

The controlled plasma glassification technology offered by IET differs significantly from any plasma technology now on the market. The process uses electrically charged gas, or plasma, to heat the waste to the point that it becomes molten. This treatment very effectively converts solid waste into a stable, glass-like product that prevents any contaminants from leaching into the environment.

The IET system offers greater, more uniform waste stream heating, and longer waste stream mixing time than other processing technologies. The result is a

higher-quality, nonleachable glass product from a wider range of feedstocks. The waste feed system is simpler as well. The designed capacity of a unit can be scaled up or down, depending on the specific waste stream requirements.

How the Company Was Created

The new technology was developed by a research team from Pacific Northwest, the Massachusetts Institute of Technology, and the private sector. The Pacific Northwest Entrepreneurial Program, one of several assistance programs managed by the Laboratory's Economic Development Office, has enabled the staff member to take a leave of absence to start the new business. Relevant technology was licensed from Pacific Northwest through Battelle, which operates the Laboratory for the U.S. Department of Energy. Pacific Northwest also provided a thermal modeling analysis of the process.

Looking Ahead

Further technology development will be conducted at IET's technology demonstration facility in Richland, Washington. The company has designed a commercial prototype, which it will fabricate and test in Richland. The prototype will be used to demonstrate the new technology to potential users. Pacific Northwest will continue to provide technical consultation. IET is exploring alliances and partnerships with companies in the waste treatment field to meet needs of industry, the U.S. Departments of Energy and Defense, and municipalities.

- Characterization of the slag and the leachability of its components
- Quantification of the environmental benefits of the process

The results show that the process achieved a substantial volume reduction of the ash, a very stable, nonleachable solid product, and low offgas levels.

DESCRIPTION AND OPERATING EXPERIENCE OF A PLASMA-ARC, ASBESTOS-VITRIFICATION UNIT

J.L. Frame
ARCPROCESS, Inc.
S.D. Hickel and G. J. Hanus
PHOENIX Solutions Co.
D. H. Davis, K. J. Hewlett, D. M. Bennert
Envitco, Inc.

ABSTRACT

A production scale, mobile waste treatment system has been constructed and demonstrated on asbestos material by ARCPROCESS Inc. The system has been deployed to treat several million pounds of excess South African amosite asbestos currently being held in inventory by the U.S. Government. The materials are being vitrified without additives to produce a glass wasteform that can be recycled to a practical use or landfilled. The heart of the system is a 500 kW plasma arc torch supplied by PHOENIX Solutions. The torch is configured to start non-transferred and shift on-the-fly from non-transferred to transferred operation. The torch is mounted with a gimballed, ball seal which seals the furnace-torch positioning interface and allows pitch and extension action. The vitrification reactor is a highly insulated tank designed and constructed by Envitco, Inc. allowing for either continuous or batch operation. The vitrification unit (torch and tank) is integrated with a semi-automatic feed system and off-gas treatment train, complete with HEPA filtration. The melter, torch system, cooling system, off-gas treatment system, air compressor and power supplies are all mounted on a single trailer to facilitate moving and set-up. The treatment train is designed for continuous operation at a rate of approximately 1000 lb/hr.

Although being demonstrated on obsolete inventory asbestos, the system can be applied to melting ash (bottom, fly ash or a mixture of the two), concrete or other asbestos-containing wastes including construction debris.

This paper will review the melter design approach and plasma torch system and various operational processing characteristics. Asbestos feed characteristics, processing techniques, plasma heating systems features and furnace characteristics will be discussed.

HIGH-TEMPERATURE REPROCESSING OF SOLID RADIOACTIVE WASTE IN PLASMA SHAFT FURNACE

I.A. Sobolev, S.A Dmitriev, F.A Lifanov, A.E. Savkin, I.A. Knjazev, V.N. Popkov,
M.A. Polkanov, S.M. Golobokov, S.U. Shvetzov
Moscow Scientific & Industrial Association RADON
Sergiev Posad, Russia

ABSTRACT

At SIA RADON the research on the application of plasma technology for the reprocessing of solid radioactive waste (SRW) of various morphological composition in shaft kilns of various designs are examined.

The experiments were carried out in an experimental shaft furnace with a capacity up to 25 kg/h using a wide range of SRW surrogates. The composition of simulators include cellulose containing materials and inorganic components (glass, metal scrap) and complex polymers (polyethylene, ion-exchange resins), spent thermal insulation (mineral cotton), soil, ground, and electrical cable.

Spent ion-exchange resin reprocessing with moisture content 50-55 % in a mixture of paper and cloth for inorganic components in the waste, and ground, fluxes 10-15 % by wt. A volume reduction of 17-36 times and a waste weight reduction of 3-5 times were obtained.

The results of the experiments show, that the volatilization of the primary off-gas filtration through the waste layer and an increase of temperature in the horizon of the loading cause significant increase of radionuclides most of all, cesium carrying away with the gas phase.

With a temperature in the melt bath of 1500-1600 °C the melting of ash and other inorganic components of the waste is ensured. The solidified slag is mainly crystalline, but can contain a fair quantity of glass phase. Its chemical stability is rather high; the leach rate of cesium does not exceed 10^{-5} gr/cm^2•day. The leaching rates of strontium and alpha-nuclides are 1-3 orders of magnitude less.

The results of the conducted research show that the considered technology is widely applicable for reprocessed radioactive waste. The advantages are mobility in regulating of the thermal conditions, small dimensions of the furnace, the possibility of full automation and remote control. Results recommend the developed design of the furnace as a technology for processing the waste of various compositions and morphology, including ones from NPPs.

APPLICATION OF PLASMA-INDUCTION HYBRID MELTER TO THE RESEARCH ON VOLUME REDUCTION AND STABILIZATION OF LOW LEVEL RADIOACTIVE SOLID WASTE

Takakuni Hirabayashi, Katuo Kanazawa, and Kazuo Fujiki
Japan Atomic Energy Research Institute
Kazuki Yamate and Daihachiro Sakurai
Radtech Corp.
Hideyuki Ikenoya
Mitsubishi Materials Corp.

ABSTRACT

Plasma-Induction Hybrid Melter is installed in Japan Atomic Energy Research Institute in March 1998. More than ten test operations were held in these months. It is confirmed that any waste like as concrete and others can be melted and all functions of the system can run well as the plan. Various tests on the solidified or/and burned nuclear waste will be held to confirm the characteristics of the products and operations.

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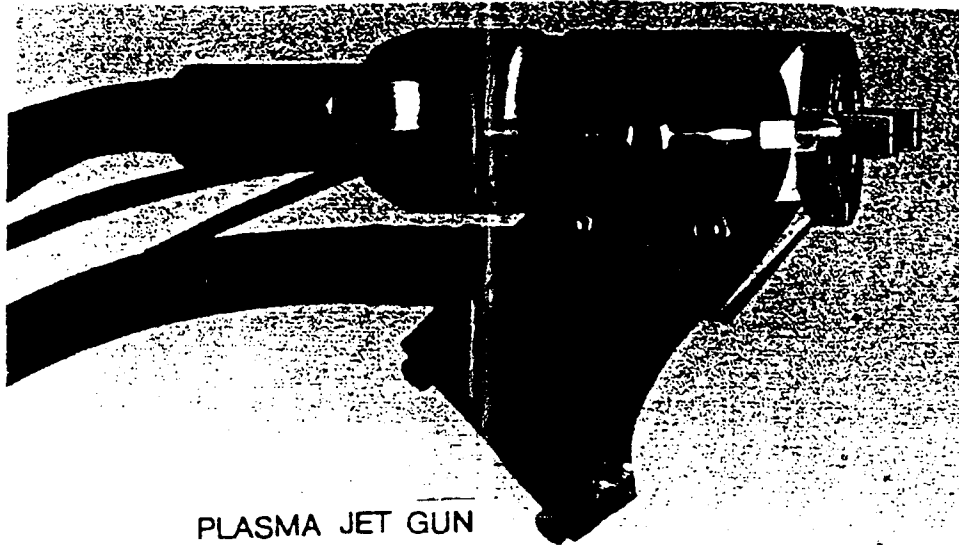# QUANTUM TECH, L.L.C

PLASMA ARC TECHNOLOGY

"A PREVIEW"

BUSINESS PLAN
FOR
QUANTUM TECH INC.

DRAFT-FOR DISCUSSION PURPOSES ONLY
MAY CONTAIN ERRORS AND OMISSIONS

PLASMA JET GUN
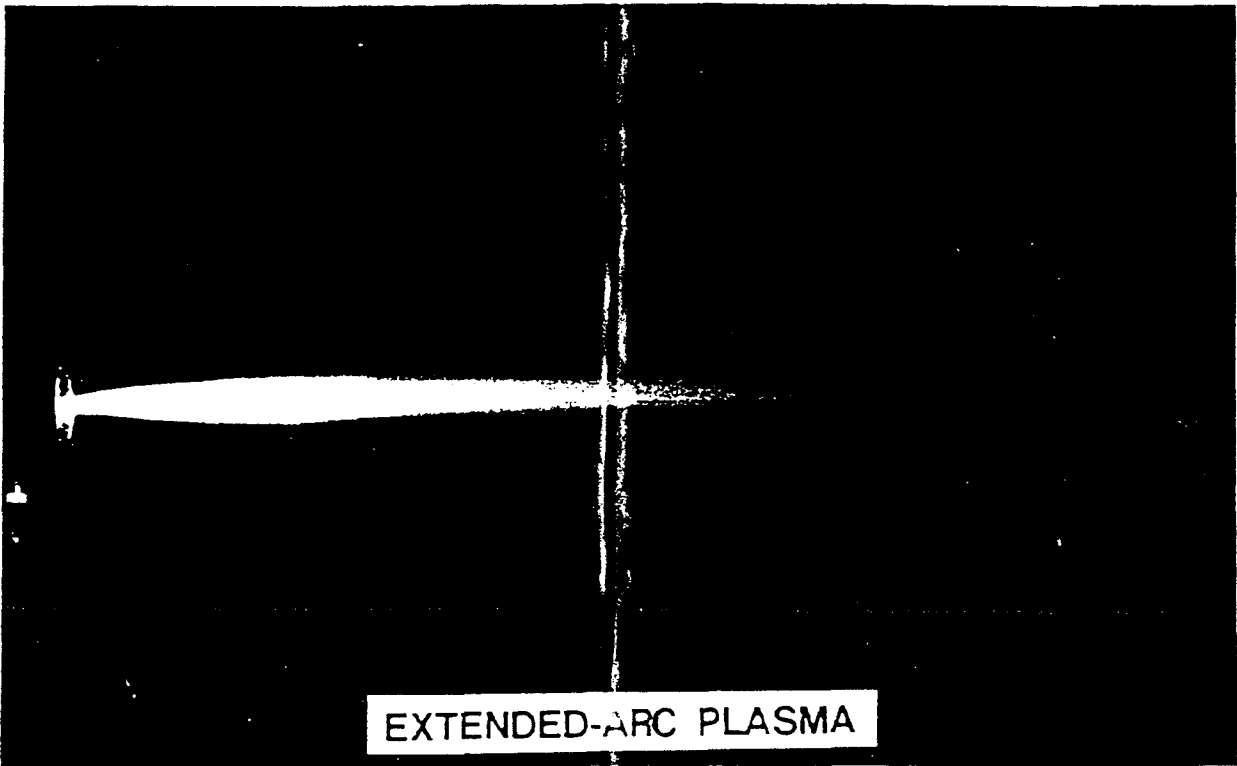
EXTENDED-ARC PLASMA
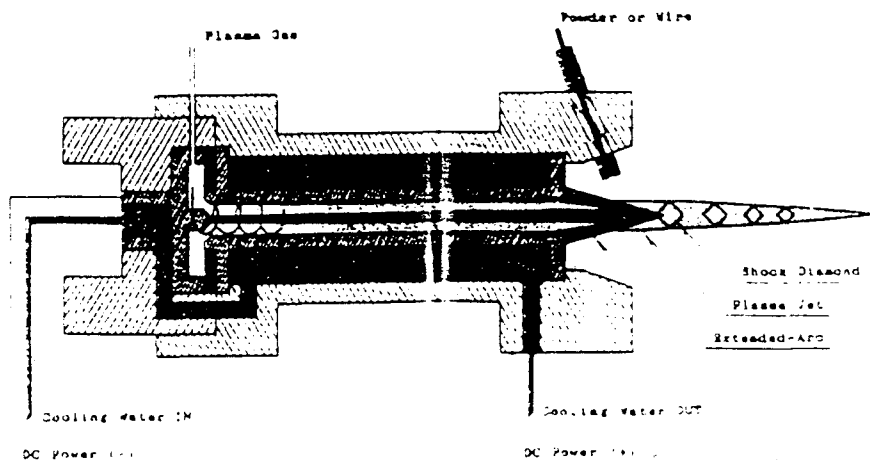
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Executive Summary

Quantum Tech, LLC, is a Texas Corporation formed to develop and license technology and providing equipment for environmentally sound recycling of waste materials into commercial products. Quantum Tech, LLC, (QTLLC) has developed a process, based on three patents held by Mr. Raja Kulkarni of Houston, for disposal of mixed wastes containing simple and complex hydrocarbons. QTLLC is committed to advancing this technology to treat the whole spectrum of non-radioactive wastes and to produce valuable end products and electricity without also producing emissions and contaminants.

Quantum Tech's unique process for treating waste and producing such by-products is the only one of its type in the world today. Quantum Tech's technology has already created a tremendous interest in the world market. Quantum Tech's principal, Raja Kulkarni, is currently engaged in seeking joint venture participation with government entities in Texas, the United States, and foreign countries and related government entities for development/construction of Quantum Tech's dual plant operations.

Presently, several government entities, domestic and foreign, have thoroughly examined Quantum Tech's waste destruction/by-product production systems and are positioned to joint venture with Quantum Tech for development/construction of Quantum Tech's dual plant operation.

QTLLC has a pilot system, in Houston, TX which can "destroy" one ton of liquid hazardous wastes per hour it has been operating under a special permit from the Texas Natural Resource Conservation Commission (TNRCC). QTLLC has developed the process to take waste materials, transform them into useful basic resources such as pure hydrogen gas, carbon black, and methanol, and generate electricity. The distinction that QTLLC has achieved is a process that produces neither emissions nor potentially dangerous residues.

"Waste to Energy" electricity plants are a familiar concept. Basically, burning waste products as a substitute for traditional materials such as coal or petroleum seems like a useful way of reducing the volume of the waste stream (to ash) while obtaining something useful -- electricity generation. Along with the heat released by burning wastes, however, many volatile substances are released into the environment. Also many substances are formed in the burning process and are contained in the ash. Some of those substances are hazardous in themselves, either toxic or carcinogenic. Some of those substances, such as carbon dioxide and carbon monoxide have their deleterious effects if they are released and accumulate in the atmosphere. Despite the best efforts to avoid such pollution, no "waste to energy" plant or system can claim an emission free operation with no contaminants produced.

It is important to understand what "burning" is to distinguish the process which QTLLC is developing. Burning is the reaction of <u>combustible</u> materials with <u>oxygen</u> in the presence of <u>heat</u>. All three components are necessary for "burning."

But combustible materials and other materials do react to the presence of heat when oxygen is not present. QTLLC has investigated such reactions under high temperatures in a vacuum and has found a bold new direction for "waste to energy."

PLASMA ARC GENERATOR -- PYROPLASMA PROCESS

The QTLLC system uses a heat source called a plasma arc generator. When electrodes are precisely shaped and distanced, a high voltage discharge can produce a zone around the electrodes of extremely high temperatures -- from 5600 to 30,000 degrees Fahrenheit. At these high temperatures, any substance within that zone disintegrates into elemental stages. All molecules dissociate into atoms, and electrons are stripped from those atoms. So the substances don't just turn into simple elemental gases, they enter a "plasma" state similar to the conditions of the surface of the sun. In the Plasma Arc Generator all substances undergo a "pyroplasma" process.

The hard work at QTLLC has paid off with the development of a cooling process -- "quenching" -- which allows for the controlled cooling of the extremely hot plasma/gases. The QTLLC reintegration process produces synthesis gas at plasma temperatures. The beauty of the process in a vacuum is those intermediary products such as NOx and SOx are _not_ formed, and emissions are physically impossible in normal operation.

PROCESS OPERATION

The beginning of the QTLLC process is the loading of the waste material directly into the primary stage of the vacuum (Graph Figure 1.A.), a holding tank (Fig. 1.B.). QTLLC expertise in metallurgy, design, fabrication and welding overcame primary problems by creating one of the world's largest vacuum vessels capable of being physically loaded with bulky items. Even though the system does not produce hazardous liquids or gases as end products, safety and caution in the initial receiving and handling of hazardous wastes are as much a part of the QTLLC process as the plasma arc generators.

Pumpable slurries, sludge, liquids are gasified and then fed directly into the plasma arc generator phase without pre-processing. Under controlled conditions of heating, most of the waste materials vaporize and flow out the top of the gasification processor. Some non-metallics and metals are collected at the bottom into a receiving tank for commercial recycling (2.C -- F.) without any emissions.

The fourth step of the system is the plasma arc generator unit. The gasified materials are preheated (3. B.) in an electric heat "U-tube" (3. A.) to maximize the efficiency of the plasma arc generator (4. A). All materials that pass through the electrode zone are disassociated into elemental stages (4. B.). As these gases are cooled (5. A - C.) in the "quenching" chamber (5. B.), they can be separated and removed as pre gases. High purity gases can be liquefied or sold in compressed gaseous form. Chlorine (6. C.) and sulfur are removed when the flow is processed by sodium hydroxide "scrubber" towers (6. A.), and pure Carbon monoxide gas and hydrogen gas (9.) can readily be collected at this stage. Also, the gases can be passed through a turbine (8. A.) to generate electricity (8. B.) to run the entire system Almost all waste streams would contain materials that would supply energy to go well beyond the power requirements of the system itself. QTLLC has found that the process can produce 30 to 40 megawatts of electricity per hour or 60,000 to 120,000 gallons of methanol, AA quality, by treating 10 tons/hr of garbage, tires or other non-radioactive hazardous material.

TNRCC INDEPENDENT LABORATORY TESTING

In the last year, the Texas Natural Resource/Conservation Commission has investigated QTLLC nascent industry as a part of its environmental protection responsibilities. The results were unequivocal. The monitoring and analysis of two different independent laboratories on several separate occasions were unable to detect any emissions during operation of the system and any contaminants in the carbon residues or system water. Even contaminants that may have entered the process by being in the water source were not detected in end products. The results demonstrate the QTLLC has surmounted the basic deficiencies of other waste processing methods and systems that are not totally benign to the environment.

THE NEXT STEP – QTLLC "PROTOTYPE" PLANT

QTLLC is moving forward to implement this patented technology and system into the world market with the full development of large-scale plant operations. As noted, there is already a great demand for this system and more can be anticipated. One key challenge is implementing this technology in the large scale plants for destroying the monumental problem of hazardous wastes. The hazardous waste problems of "high-tech" manufacturing industries present a unique opportunity to meet this challenge.

The prototypical plant will be able to process up to 200 tons of waste each day. Basically, the plant would consist of ten parallel systems, each equivalent to the single system currently operated by QTLLC in Houston. The plant would incorporate diagnostics, fabrication, recycling and power generation capabilities not currently featured in the Houston system. The physical plant would require about 30,000 square feet of space and use about 2.5 megawatts of electrical power each day. Almost all of this power would be self-generated. The physical plant would also use 200 tons of water each day in the production of 200 tons of methanol per day. The prototypical plant would create jobs for about fifteen full time employees, including support and administrative staff.

By embarking on a modular approach to new systems, QTLLC plans to hold the line on systems cost while maximizing efficiency. QTLLC "pyroplasma" process offers startling changes to municipal waste disposal, fuel production and water purification.

ABOUT MR. KULKARNI

Raja Kulkarni, the originator of QTLLC's process, grew up near Bombay, India. He put himself through the University of Bombay's undergraduate program in chemistry and physics. Upon moving to the United States, Mr. Kulkarni earned a second bachelor's degree in mechanical engineering in the area of material science, at the Milwaukee Institute of Technology. He continued his engineering studies in the field of metallurgy after he moved to Texas, and finished a Master's of Business Administration at Texas Southern University. Since becoming a United States citizen in 1975, Mr. Kulkarni has owned and successfully operated several businesses in the Houston area. He has obtained several patents in those years, and has been a great resource for improving systems and production for many other businesses.

FUNDING NEEDED FOR QUANTUM TECH'S MAJOR DUAL PLANTS

For Quantum Tech, LLC major dual plant development/construction/startup operations, funding sought and required will total as follows:

Domestic Sites: Thirty-Million Dollars USD ($30,000,000 USD).

Foreign Sites: Thirty-eight Million Dollars USD ($38,000,000 USD), except where contingencies (land site, improvements to land site, shipping, etc.) involving the foreign project development and construction may require additional capitalization. (To be so documented and noted where so pertaining).

QUANTUM TECH'S MAJOR DUAL-PLANT DEVELOPMENT

Development/Construction of Quantum Tech's major plant sites will require six to twelve months, in most cases. Houston, Texas based, world known firm of Stewart & Stevenson, Inc., will be one of the General Contractors in the development and construction of Quantum Tech's electrical generation facility, both foreign and domestic. The amount of electrcity that can be produced on a 300 ton/day plant is approximately 40-65Megawatts/hr, and/or the amount of Methanol that can be produced is about 150,000 gallons/day.

Economic Evaluation

Electrical Generation by Synthesis Gas

The production of electricity by turbo generators is in another prospect available for the use of our system. The output of the synthesis gas is approximately 800,000 cuft. of gas per hour. This is based on an input of ten tons of garbage/hr consisting of mostly organic material. The content of our syn gas is 1 part CO and 2.5 parts H_2. The purity of the syn gas is almost 100% pure due to the technology of molecular sieves.

Stewart and Stevenson one of the worlds largest producers of Turbo Generators has available several 40MW/hr machines which we can use in conjunction with our system to produce electricity. They also have available contracts to maintain and warranty the generators anywhere in the world for the life of the generator.

With a 2o ton/day unit you need an additional 10 tons of organics to produce electricity

Electrical Energy Production

Capacity Tons/Day	Output MW	Price/ kW	Revenue
30	5	$0.10	$12,000
60	10	$0.10	$24,000
90	15	$0.10	$36,000
120	20	$0.10	$48,000
240	40	$0.10	$96,000
300	**50**	**$0.10**	**$120,000**
600	100	$0.10	$240,000
720	120	$0.10	$288,000
900	150	$0.10	$360,000

The current average price for electricity is $.10 kWh

Plant Output
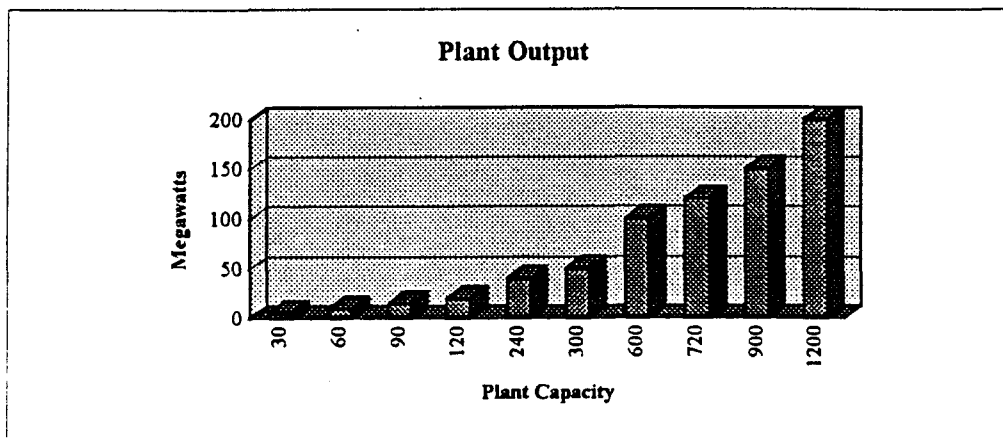
A 30 ton/day unit can produce approximately 5 to 7 Megawatts of Electricity per hour.

Electrical Generation by Synthesis Gas

The production of electricity by turbo generators is in another prospect available for the use of our system. The output of the syn gas is approximately 800,000 cft. of gas per hour. This is based on an input of ten tons of garbage/hr consisting of mostly organic material. The content of our syn gas is 1 part CO and 2.5 parts H_2. The purity of the syn gas is almost 100% pure due to the technology of molecular sieves.

Stewart and Stevenson one of the worlds largest producers of Turbo Generators has available several 40MW/hr machines which we can use in conjunction with our system to produce electricity. They also have available contracts to maintain and warranty the generators anywhere in the world for the life of the generator.

60 Hz
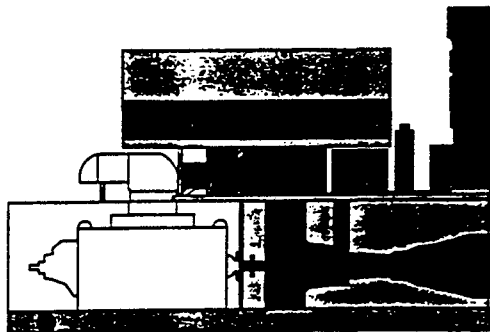
Dimensions

Baseplate Length	56' 6"
Baseplate Width	13' 6"
Enclosure Height	14 6"
Overall Length	56' 9"
Overall Width*	49' 9"
Overall Height*	36' 2"
Baseplate Foundation Load*	476,000 lb

* Includes Air Filter

50 Hz
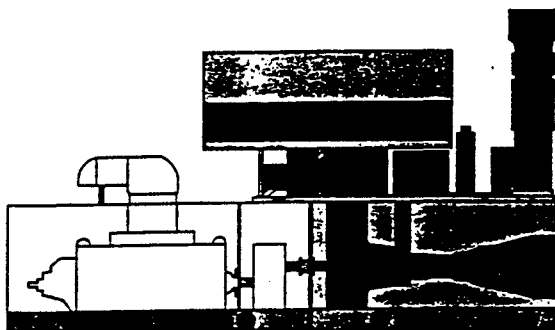
Dimensions

Baseplate Length	64' 7"
Baseplate Width	13' 6"
Enclosure Height	14' 6"
Overall Length	64' 10"
Overall Width*	49' 3"
Overall Height*	37' 11"
Baseplate Foundation Load*	522,000 lb

* Includes Air Filter

LM6000 Gas Turbine
60-Hz* Generator Set Performance

Site Conditions:
60% rh, sea level
No inlet/exhaust losses
Natural gas fuel
No water or steam injection

– – Exhaust gas flow, lb/sec
· · · · Exhaust gas temperature, ° F
— — Fuel Flow, MMBtu/hr

* For 50-Hz, kW output is approximately 1.5% less.

The Stewart & Stevenson air management system provides peak power output by controlling operating temperature.
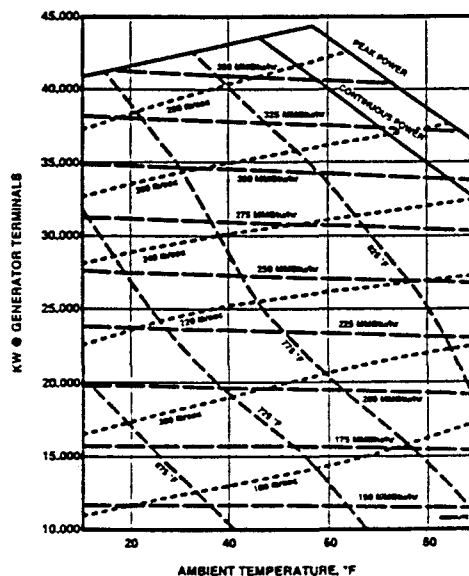
Stewart & Stevenson
International, Inc.

P.O. Box 1637
Houston, Texas 77251-1637
Tel: (713) 868-7700
Fax: (713) 868-7697

Courier Deliveries:
707 North Loop West
Houston, Texas 77008
WX: 910-881-1636
TELEX: 794221 SNSCPW HOU

Aeroderivative Industrial Gas Turbine Generator Sets

		LM1600	LM2500	LM2500 STIG 50	LM5000	LM5000 STIG 80	LM5000 STIG 120	LM6000
60 Hz	ISO Continuous kW*	13440	22800	28050	34400	48100	51620	40760
	Btu/kWH (LVH)*	9545	9280	8325	9180	8070	7790	8590
	Exhaust Flow (#/sec)	100	152	168	268	324	339	277
	Exhaust Gas Temp. (° F)	909	975	926	813	766	741	864
50 Hz	ISO Continuous kW*	13440	21960	27020	34500	46360	49600	40270
	Btu/kWH (LVH)*	9545	9550	8620	9290	8340	8110	8695
	Exhaust Flow (#/sec)	100	148	168	275	330	344	277
	Exhaust Gas Temp. (° F)	909	1008	941	811	767	752	864

* Includes generator and gearbox losses. Ratings at 59° F, sea level, no inlet/exhaust losses, natural gas fuel

Ratings

Hz Generator Sets

	Base (kW)*	Btu/kWH (LHV)*	No. of Shafts	Turbine Shaft Speed	Exhaust Flow (#/sec)	Exhaust Gas Temp. (° F)
501-KB5	3864	12,245	1	14,200	34.4	1071
501-KB7	4610	12,120	1	14,600	44.9	996
LM1600	13,440	9545	3	7000	100.0	909
LM2500	22,800	9280	2	3600	152.0	975
LM2500 STIG 50	28,050	8325	2	3600	168.0	926
LM5000 PC	34,400	9180	3	3600	268.0	813
LM6000 PA	40,760	8590	2	3600	277.0	864
LM5000 STIG 80	48,100	8070	3	3600	324.0	766
LM5000 STIG 120	51,620	7790	3	3600	339.0	741

50 Hz Generator Sets

	Base (kW)*	Btu/kWH (LHV)*	No. of Shafts	Turbine Shaft Speed	Exhaust Flow (#/sec)	Exhaust Gas Temp. (° F)
501-KB5	3864	12,245	1	14,200	34.4	1071
501-KB7	4610	12,120	1	14,600	44.9	996
LM1600	13,440	9545	3	7000	100.0	909
LM2500	21,960	9550	2	3000	148.0	1008
LM2500 STIG 50	27,020	8620	2	3000	168.0	941
LM5000 PC	34,500	9290	3	3000	275.0	811
5000 PA	40,270	8695	2	3600	277.0	864
LM5000 STIG 80	46,360	8340	3	3000	330.0	767
LM5000 STIG 120	49,600	8110	3	3000	344.0	752

Mechanical Drive Sets

	Base (SHP)*	Btu/SHP-hr (LHV)*	No. of Shafts	Turbine Shaft Speed	Exhaust Flow (#/sec)	Exhaust Gas Temp. (° F)
501-KSS	5510	8971	2	13,820	35.0	1092
LM1600	18,745	6845	3	7000	100.0	909
LM2500	31,235	6770	2	3600	148.0	1008
LM5000	46,975	6725	3	3600	275.0	811
LM6000	55,545	6305	2	3600	277.0	864

* includes generator and gearbox losses.

Ratings at 59° F, sea level, no inlet/exhaust losses, natural gas fuel

Electrical Energy Production

The current average price for electrcity is $.10 kwh

With a 20 ton/day unit you need an additional 10 tons of organics to produce electicity

A 30 ton/day unit can produce approximately 5-7 Megawatts of Electricity per Hour

30 ton/day	0.05 kwh	5 Meg	250 $/hr	6000 $/day
30 ton/day	0.10 kwh	5 Meg	500 $/hr	12000 $/day
60 ton/day	0.10 kwh	10 Meg	1000 $/hr	24000 $/day
90 ton/day	0.10 kwh	15 Meg	1500 $/hr	36000 $/day
120 ton/day	0.10 kwh	20 Meg	2000 $/hr	48000 $/day
240 ton/day	0.10 kwh	40 Meg	4000 $/hr	96000 $/day
300 ton/day	0.10 kwh	50 Meg	5000 $/hr	120000 $/day
600 ton/day	0.10 kwh	100 Meg	10000 $/hr	240000 $/day
720 ton/day	0.10 kwh	120 Meg	12000 $/hr	288000 $/day
900 ton/day	0.10 kwh	150 Meg	15000 $/hr	360000 $/day

Currently the State of Texas Pays us $.85/tire to shred them

30 tons/day equals	60000 lbs	2727.27 dollars/day		90.91 $/ton

On a Daily Basis for a 30 ton/day plant . 14727.27

On a Yearly Basis for a 30 ton/day plant   4418182 300 days/yr   736.36 $/ton

On a 600 ton/day dual plant of Electricity and Methanol

Electrical Revenue   147272.7 per/day
Methanol Revenue   147272.7 per/day

Total   294545.5 per/day

On a yearly Basis   88363636 300 days/yr

Electrical Power Generation

Tons of Organic Feedstock on Per Day Basis

Dollar Amount Made on Electrical Power Generation

Dollars

400000
350000
300000
250000
200000
150000
100000
50000
0

30
60
90
120
240
300
600
720
900

Dollars

Tons of Organic Feedstock on Per Day Basis
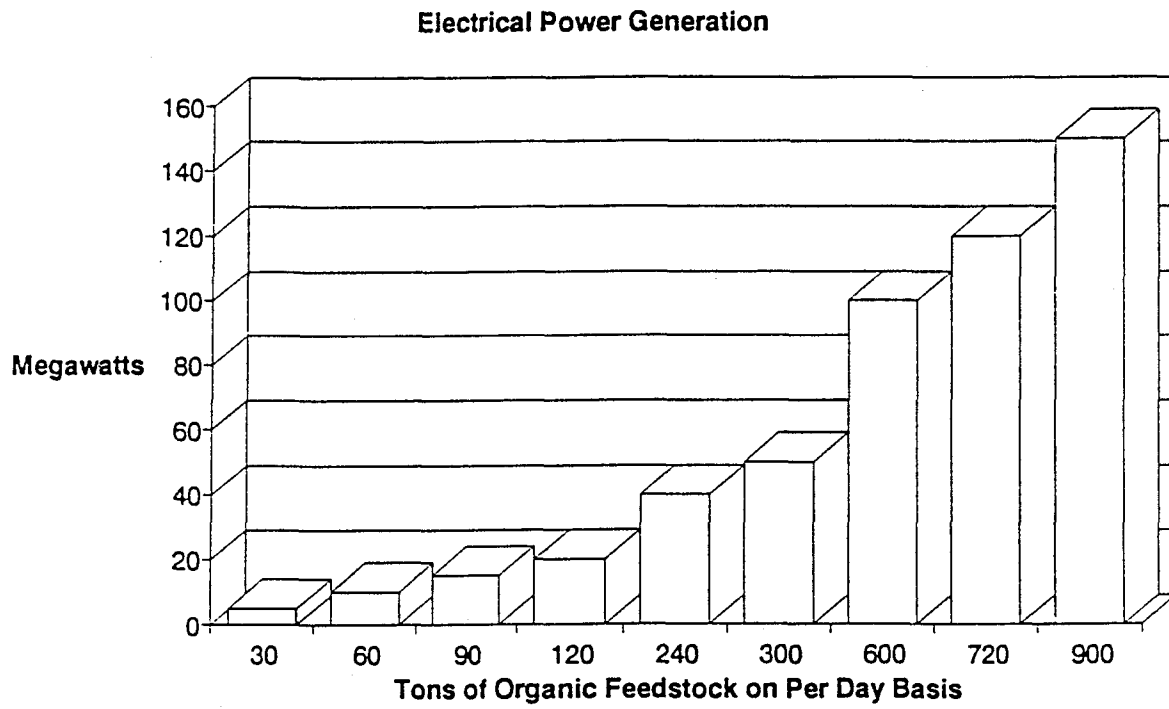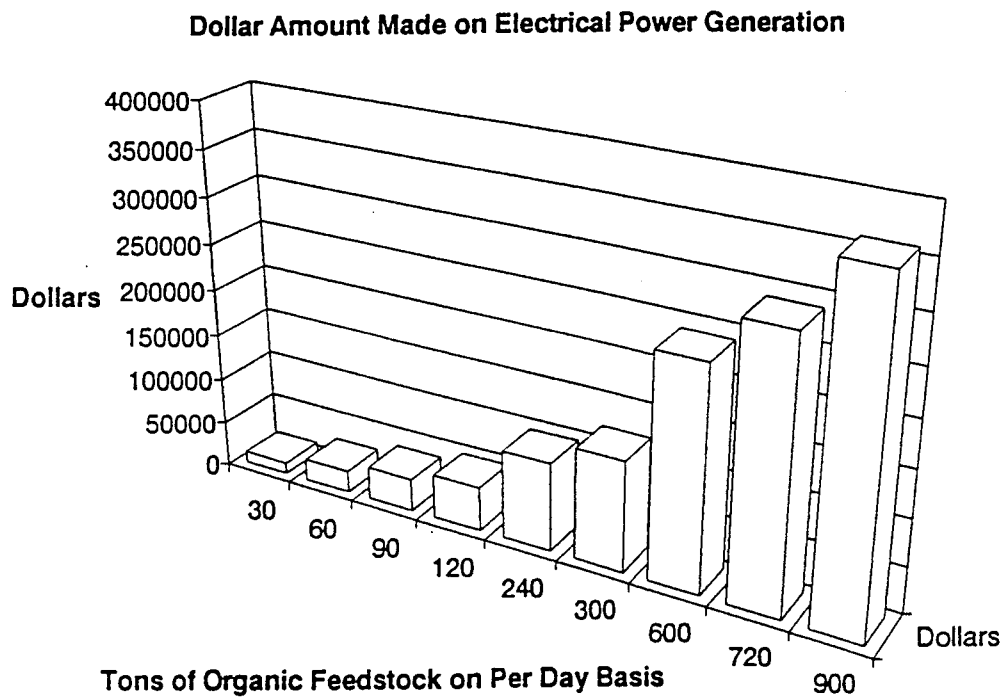
Quantum Tech, LLC

Possible Comerical Applications

Each unit can process 20 tons/day of organic feedstock.
For a large scale plant of 200 tons/day = 10x Individual units needed.

Methanol Production

The current average price for Methanol is $0.00   0.80 gallon

For a 20 ton/day unit we can produce 10,000 gallons of Methanol

20 tons/day	0.80 per/gallo	10000 gallons	8000 dollars/day
40 tons/day	0.80 per/gallo	20000 gallons	16000 dollars/day
60 tons/day	0.80 per/gallo	30000 gallons	24000 dollars/day
80 tons/day	0.80 per/gallo	40000 gallons	32000 dollars/day
100 tons/day	0.80 per/gallo	50000 gallons	40000 dollars/day
200 tons/day	0.80 per/gallo	100000 gallons	80000 dollars/day
300 tons/day	0.80 per/gallo	150000 gallons	120000 dollars/day
400 tons/day	0.80 per/gallo	200000 gallons	160000 dollars/day
800 tons/day	0.80 per/gallo	400000 gallons	320000 dollars/day
1000 tons/day	0.80 per/gallo	500000 gallons	400000 dollars/day

Currently the State of Texas Pays us $.85/tire to shred them

20 tons/day	equals	40000 lbs	1818.18 dollars/day	90.91 $/ton

On a Daily Basis for a 20 ton/day plant   9818.182

On a Yearly Basis for a 20 ton/day plant   2945455 300 days/yr   490.91 $/ton

Methanol Production on a Per/Ton Basis
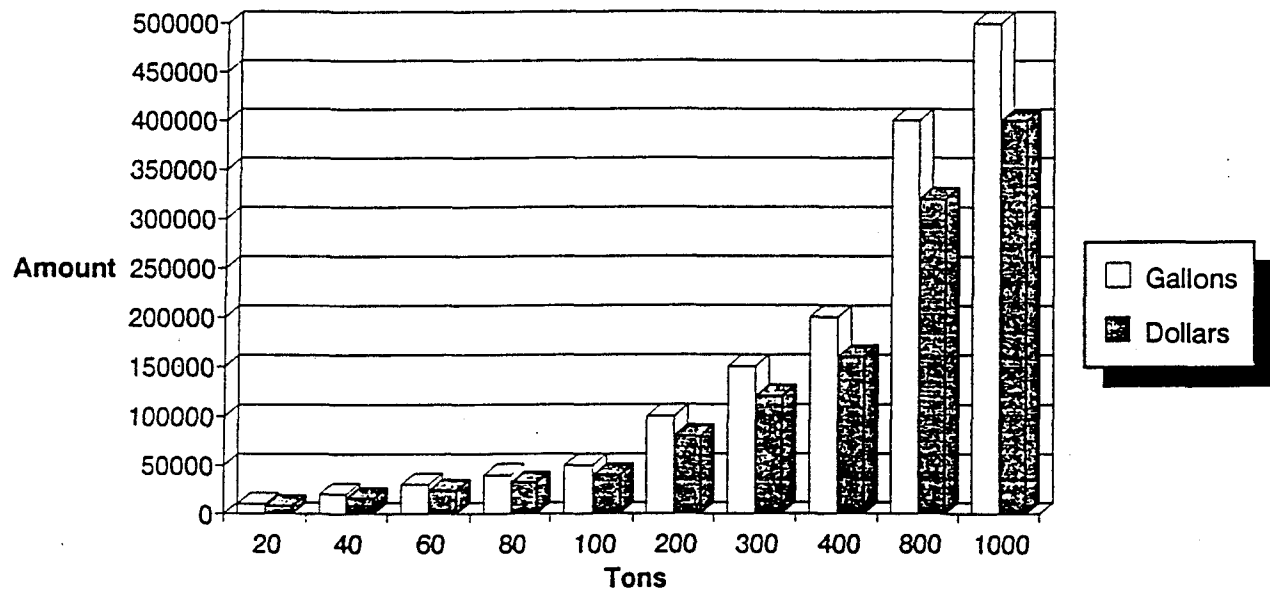
Methanol / Acetic Acid Production
by Synthesis Gas

The production of Methanol/ Acetic Acid is in another prospect available for the use of our system. The output of the synthesis gas is approximately 800,000 cuft. of gas per hour. This is based on an input of ten tons of organic waste/hr consisting of mostly of 60 - 70% carbon. The content of our syn gas is 1 part CO and 2.5 parts H_2. The purity of the syn gas is almost 100% due to the technology of molecular sieves.

Haldor Topsoe world renown for their Methanol Process, will be chosen as the prime contractor for our Methanol plant. To produce Acetic Acid from Methanol we will be incorporating the Monsanto Process.

For every 100 tons of organics processed we can manufacture up 50,000 gallons of Methanol/Acetic Acid.

Quantum Tech, LLC

Possible Commercial Applications

Each unit can process 20 tons/day of organic Feedstock.
For a large scale plant of 200 tons/day = 10x Individual units needed.

Methanol Production

Capacity Tons/day	Price/gal.	Gallons	Revenue
20	$0.80	10,000	$8,000
40	$0.80	20,000	$16,000
60	$0.80	30,000	$24,000
80	$0.80	40,000	$32,000
100	$0.80	50,000	$40,000
200	**$0.80**	**100,000**	**$80,000**
300	$0.80	150,000	$120,000
400	$0.80	200,000	$160,000
800	$0.80	400,000	$320,000
1000	$0.80	500,000	$400,000

The current average price for Methanol is $0.80 per gallon

For each 20 ton/day unit we can produce 10,000 gallons of Methanol

Electrical Energy

1993 U.S. Methanol End Uses
(Total 1,995 MM gallons)

MTBE 34.7%
(693 MM gallons)

Formaldehyde
25.9%
(516 MM gallons)

Other 9.5% (Includes Alternative
Fuels M85/M100 at less than 0.3%)

Dimethyl Terephthalate 1.7%

Methyl Methacrylate 3.2%

Methylamines 2.5%

Acetic Acid
10.8% (216 MM gallons)

Chloramethanes
4.4%

Solvents
4.3%

Methylhalides,
3.0%
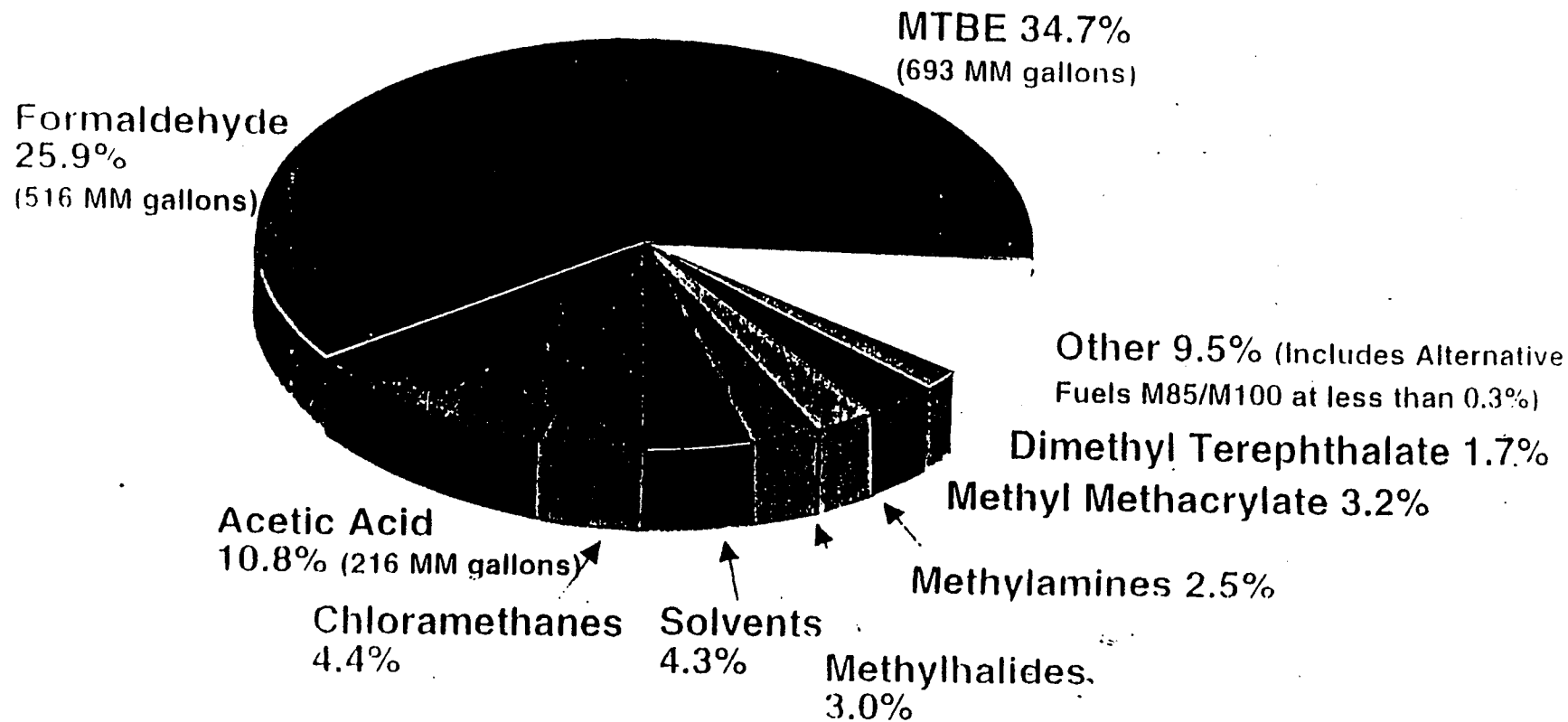
1992 U.S. Methanol End Uses
(Total 1,780 MM gallons)

MTBE 31.0%
(551 MM gallons)

Formaldehyde
26.6%
(474 MM gallons)

Other 10.0%
(Includes Alternative Fuels
M85/M100 at less than 0.3%)

Dimethyl Terephthalate 1.9%
Methyl Methacrylate 3.6%

Methylamines 2.8%

Acetic Acid
11.2% (200 MM gallons)

Chloromethanes
4.9%

Solvents
4.6%

Methylhalides
3.4%

Quantum Tech, LLC

Possible Commercial Applications

Each unit can process 20 tons/day of organic Feedstock.
For a large scale plant of 200 tons/day = 10x Individual units needed.

Methanol Production

Capacity Tons/day	Price/gal.	Gallons	Revenue
20	$0.80	10,000	$8,000
40	$0.80	20,000	$16,000
60	$0.80	30,000	$24,000
80	$0.80	40,000	$32,000
100	$0.80	50,000	$40,000
200	$0.80	100,000	$80,000
300	$0.80	150,000	$120,000
400	$0.80	200,000	$160,000
800	$0.80	400,000	$320,000
1000	$0.80	500,000	$400,000

Plant Output

The current average price for Methanol is $0.80 per gallon

For each 20 ton/day unit we can produce 10,000 gallons of Methanol

World Methanol Supply/Demand Balance

(In metric tons-000)

	1994	1995	1996
Supply:			
Nameplate Capacity	24,200	26,000	27,800
Production: assume 92% utilization	22,264	23,920	25,576
Demand:			
Formaldehyde	7,842	7,987	8,133
MTBE	5,800	6,951	8,211
Acetic Acid	1,522	1,546	1,546
Solvents	780	805	822
Gasoline/fuels	410	415	385
DMT	636	638	638
Methyl Methacrylate	605	642	652
Misc. chemical	4,609	4,930	4,842
Misc. other	220	225	230
Sub-total	22,424	24,139	25,459
Balance	<160>	<219>	117
Balance in Gallons/Day	<145,973>	<199,800>	106,743

Possible Markets for the System

Summary: The pyro-plasma system converts any type hazardous or non hazardous organic materials, to the listed Byproducts (**20 ton/day unit shown**):

Organic Feed stocks:

1. **Hazardous Material:**

a) Benzene

b) Carbon Tetra-Chloride

c) PCB's

d) Paint Thinners

e) Industrial Solvents

f) All types of Organic Waste Residues with metals and non-metals

g) Household Chemicals

2. **NON-Hazardous Material:**

a) Used Motor Oil

b) Municipal Sewage

c) Heavy Oil Refinery Residues

3. **Solids**

a) Garbage (Waste Food products, plastics, papers)

b) Tires

c) Medical Waste

d) Tar

Byproducts:

1 Carbon Black (10,000) lb.

2 Hydrogen (40,000 cuft.)

3 CO and H2 (Carbon Monoxide and Hydrogen) (80,000 cuft.)

4 Electricity (5-7 Megawatts)

5 Fresh Water (5 gpm)

6 Methanol (10,000 gallons); which can be synthesized to the following:

a) Acetic Acid

b) MTBE

c) as a complimentary in the production of Plastics

d) Formaldehyde

Pyro-plasma Process To Convert Organics to Energy

Electricity

Solid Organic Waste Material

Synthesis Gas of CO +H2

PLASMA

Synthesis Gas of CO + H2

Turn Organic Material into a GAS

WORLD CONSUMPTION

Process Converts 300 tons/day of Organic Material to
Either 50 Megawatts of Electricity or 100,000 gallons of Methanol

QUANTUM TECH, LLC

Liquid Organic Waste Material

Methanol

MFT 61 (120000g)

S
T
P

30

MOL SIEVES 35

24

V- 23

C 1120

17

VT 12

VC 27 22

VC 13

29 P C 25 C

9
8
VT

20'-0"

PACDC 21

C 16

10 SGC 7 VT

4 3

25'-0"

HD MD 28

CC

26

SC 15

R

20

VP 14

11 9

FM 6 ECM 5 1 GP1

HE 27

VP 14A

PC 19

C 18

HMRT

31

LUNCH
RECREATION

LR

HR

LABORATORY

32 32

QUANTUM TECH INC.

1 GARBAGE RECIEVING TANK
2 GARBAGE SCREENING BELT
3 NON MAGNETIC MATERIAL TANK
4 MAGNETIC MATERIAL TANK
5 EDDY CURRENT MAGNET
6 FERRO MAGNET
7 VACUM TANK 1
8 VACUM TANK 2
9 FAN TUBING
10 TOR OR THE GAS CONDENSER

11 CONTROLS
12 WATER TANKS
13 WATER CHILLERS
14 VACUM PUMPS
15 SHAKER CONVEYORS
16 CARBON TANKS
17 1300 F FURNACE
18 CARBON TANKS
19 PLASMA CONTROLS
20 PLASMA REACTORS

21 PLASMA ACDC CONVERTERS
22 WATER CHILLERS
23 WATER TANKS
24 SODIUM HYDROXIDE TANKS
25 COMPRESSORS
26 CATALYTIC CONVERTERS
27 WATER CHILLERS
28 METHANE DISTILLATION
29 METHANE PUMPS
30 METHANE FARM TANKS

31 LAB
32 LADIES ROOM
33 MENS ROOM
34 LUNCH & RECREATION

↑ ESCAPE ROUTES

35 MOLECULAR SIEVES

HMRT HAZARDOUS MATERIAL RECIEVING TANKS

I. D.

BLOCK FLOW DIAGRAM
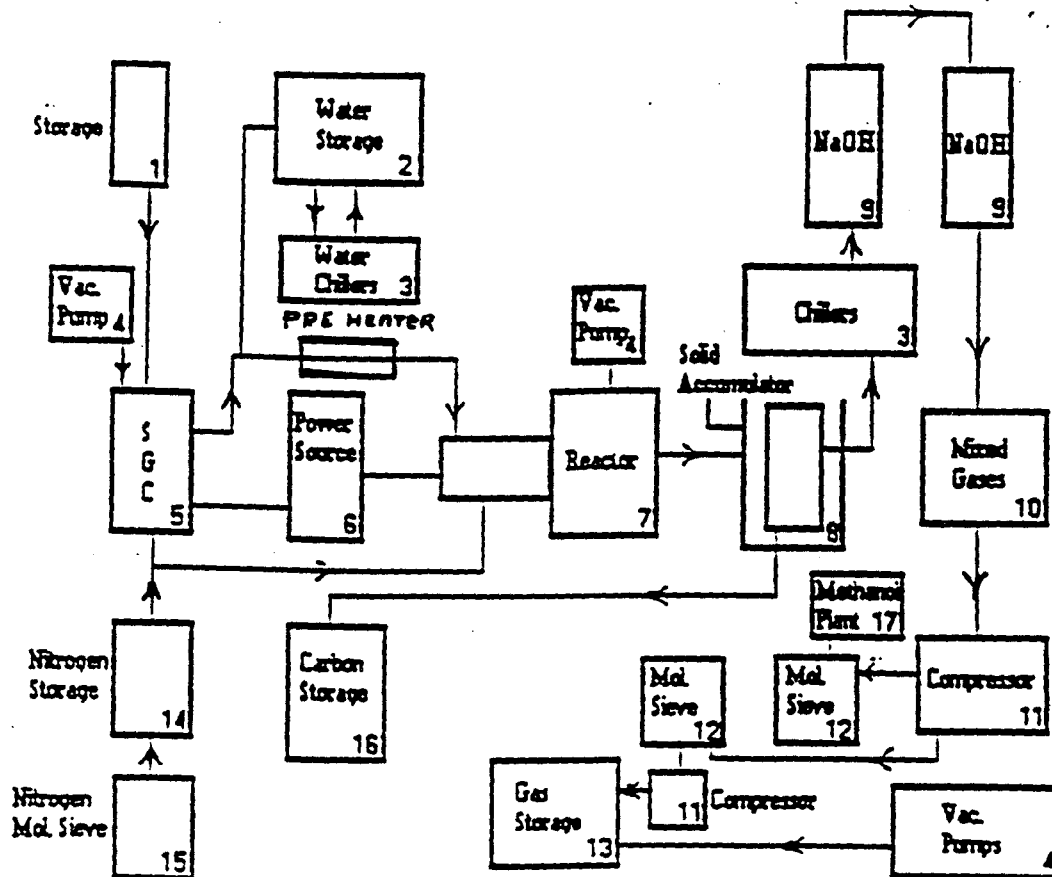
Profit and Loss Statement

Quantum Tech, LLC

Cost $ 2,500,000.00
For converting organic waste material into a synthesis gas of CO & H2.
For a unit that can process 20 US tons/day of organic wastes in Texas, USA.
For larger units, they are merely multiples of the base 20 ton/day unit.
* However the cost is not proportional.

For the given cost it is possible to process one of the three below.

20 US Ton Capacity Processing Power   **Daily Sales**

1) Treatment of Hazardous Material
At a daily rate of one machine operating   20 hr./day
At a disposal rate of 5 gallons/min   6,000 gal/day
At a weight of 7lbs/gallon   42,000 lb./day
At a sales rate of $3.00/gallon $18,000

OR   **Daily Sales**

2) Garbage Collection
At a daily rate of one machine operating   20 hr./day
At a disposal rate of 1 ton/hr   20 tons/day

At an Average Price of $20.00 per US ton $400.00

OR   **Daily Sales**

3) Tire Disposal
At a daily rate of one machine operating   20 hr./day
At a disposal rate of 2000 lb./hr   40,000 lb./day
At an Average Price of $0.80 per tire for (Texas, US) . $1,711.23 per day

For a 20 ton/day Hazardous material plant that costs $ $2,500,000.
Feed Processing and Synthesis Gas Production Only

Sales		Daily	(20 days) Monthly	(12 months) Yearly
From 1		$18,000	$3,600,000	$43,200,000
Cost Of Sales				
Utilities				
Gas		$200	$4,000	$48,000
Water		$100	$2,000	$24,000
Electricity 1 Plasma Machines $20/hr		$400	$8,000	$96,000
Labor 4X $10/hr		$400	$8,000	$96,000
Insurance $7/day/man		$28	$560	$6,720
Taxes 11% of Payroll		$44	$880	$10,560
Total Cost Of Sales		$1,172	$23,440	$281,280
Gross Margin		$16,828	$336,560	$4,038,720

Administrative Expenses	Daily	(20 days) Monthly	(12 Months) Yearly
Administrative salaries	$230	$4,600	$55,200
Advertising	$20	$400	$4,800
Depreciation	$195	$3,900	$46,800
Entertainment	$10	$200	$2,400
Dues	$10	$200	$2,400
Employee Benefits	$40	$800	$9,600
Equipment Rental	$60	$1,200	$14,400
Legal Accounting	$50	$1,000	$12,000
Licensees	$20	$400	$4,800
Maintenance	$30	$600	$7,200
Misc.	$30	$600	$7,200
Office Supplies	$20	$400	$4,800
Sales	$50	$1,000	$12,000
Rentals	$20	$400	$4,800
Telephone	$10	$200	$2,400
Travel	$10	$200	$2,400
Total Admin. Expenses	$805	$16,100	$193,200
Net Income Before Taxes	$16,023	$320,460	$3,845,520
Federal Income TAX (22%)	$3,525	$70,501	$846,014
Net Income	$12,498	$249,959	$2,999,506

* These are approx. figures and Quantum Tech, LLC will not be held liable for them.
Independent Plants will vary.
* All figures are rounded to nearest dollar.

Possible Sell Of Byproducts from the synthesis gas produced from:

For a 20 ton/day unit
The process produces 80,000 cuft of syn gas of CO and H2 which can be used to make Methanol,
Electricity, or other Various Products. Methanol can also be used to synthesize Acetic Acid.

20 ton/day unit
Individual Cost of each Methanol plant is $ 5,000,000
Total Plant cost is $ 8,000,000 $8,000 /day
Methanol $0.80 /gallon   10,000 gallons/day

200 ton/day unit
Individual Cost of each Methanol plant is $ 18,000,000
Total Plant cost is $ 40,000,000 $80,000 /day
Methanol $0.80 /gallon   100,000 gallons/day

* However Smaller than 200 US Tons/day to just Produce Methanol is not feasible.

Use of Hazardous Material as Feedstock is shown,.

Sales	Daily	(20 days) Monthly	(12 Months) Yearly	Yearly 200 tons/day
From 1	$18,000	$360,000	$4,320,000	$43,200,000
ethanol	$8,000	$160,000	$1,920,000	$19,200,000
Cost Of Sales				
Utilities				
Gas	$200	$4,000	$48,000	$480,000
Electricity 1 Plasma machine				10 machines
$20/hr	$400	$8,000	$96,000	$960,000
Water	$70	$1,400	$16,800	$168,000
Labor 6X $10/hr	$600	$12,000	$144,000	$1,440,000
Insurance $7/day/man	$42	$840	$10,080	$100,800
Taxes 11% of Payroll	$66	$1,320	$15,840	$158,400
Total Cost Of Sales	$1,378	$27,560	$330,720	$3,307,200
Gross Margin	$24,622	$492,440	$5,909,280	$59,092,800

Administrative Expenses	Daily	(20 days) Monthly	(12 Months) Yearly	Yearly 200 ton/day
Administrative salaries	$230	$4,600	$55,200	$55,200
Advertising	$20	$400	$4,800	$4,800
Depreciation	$195	$3,900	$46,800	$46,800
Entertainment	$10	$200	$2,400	$2,400
Dues	$10	$200	$2,400	$2,400
Employee Benefits	$20	$400	$4,800	$4,800
Equipment Rental	$30	$600	$7,200	$7,200
Legal Accounting	$50	$1,000	$12,000	$12,000
Licensees	$100	$2,000	$24,000	$24,000
Maintenance	$30	$600	$7,200	$7,200
Misc.	$30	$600	$7,200	$7,200
Office Supplies	$10	$200	$2,400	$2,400
Sales	$50	$1,000	$12,000	$12,000
Rentals	$20	$400	$4,800	$4,800
Telephone	$10	$200	$2,400	$2,400
Travel	$10	$200	$2,400	$2,400
Total Admin. Expenses	$825	$16,500	$198,000	$198,000
Net Income Before Taxes	$23,797	$713,910	$8,566,920	$50,525,880
leral Income TAX (22%)	$5,235	$157,060	$1,884,722	$11,115,694
Net Income	$18,562	$556,850	$6,682,198	$39,410,186

* These are approx. figures and Quantum Tech, LLC will not be held liable for them.

We need an extra 10 tons/day unit for a Gas Turbine's BTU Requirements

Total Possible Sales for a 30 ton/day unit
Individual Cost for an Electrical Plant $ 3,000,000
Total Plant Cost is $7,000,000
Electricity $0.05/kwh   4 Megawatts $4,800 per/day

Total Possible Sales for a 300 ton/day unit
Individual Cost for an Electrical Plant $ 16,000,000
Total Plant Cost is $35,000,000
Electricity $0.05 /kWh   40 Megawatts $48,000 per/day

Sales	Daily	Monthly	Yearly	Yearly 300 ton/day
From 1	$18,000	$540,000	$6,480,000	$64,800,000
Electricity	$4,800	$144,000	$1,728,000	$17,280,000
Cost Of Sales				
Utilities				
Gas	$200	$6,000	$72,000	$720,000
Electricity 3 Plasma machine				30 machines
$60/hr	$1,200	$36,000	$432,000	$4,320,000
Water	$70	$2,100	$25,200	$252,000
Labor 6X $10/hr	$600	$18,000	$216,000	$2,160,000
Insurance $7/day/man	$42	$1,260	$15,120	$151,200
Taxes 11 % of Payroll	$66	$1,980	$23,760	$237,600
Total Cost Of Sales	$2,178	$65,340	$784,080	$7,840,800
Gross Margin	$20,622	$618,660	$7,423,920	$74,239,200

Administrative Expenses	Daily	Monthly	Yearly	Yearly 300 ton/day
Administrative salaries	$230	$6,900	$82,800	$82,800
Advertising	$20	$600	$7,200	$7,200
Depreciation	$195	$5,850	$70,200	$70,200
Entertainment	$10	$300	$3,600	$3,600
Dues	$10	$300	$3,600	$3,600
Employee Benefits	$20	$600	$7,200	$7,200
Equipment Rental	$30	$900	$10,800	$10,800
Legal Accounting	$50	$1,500	$18,000	$18,000
Licensees	$100	$3,000	$36,000	$36,000
Maintenance	$30	$900	$10,800	$10,800
Misc.	$30	$900	$10,800	$10,800
Office Supplies	$10	$300	$3,600	$3,600
Sales	$70	$2,100	$25,200	$25,200
Rentals	$20	$600	$7,200	$7,200
Telephone	$10	$300	$3,600	$3,600
Travel	$10	$300	$3,600	$3,600
Total Admin. Expenses	$845	$25,350	$304,200	$304,200
Net Income Before Taxes	$19,777	$593,310	$7,119,720	$73,935,000
Federal Income TAX (22%)	$4,351	$130,528	$1,566,338	$16,265,700
Net Income	$15,426	$462,782	$5,553,382	$57,669,300

* These are approx. figures and Quantum Tech, LLC. will not be held liable for them.
Individual plant expenses will vary.

ECONOMIC EVALUATION - HAZARDOUS MATERIALS' PLANT

INTRODUCTION

The overall economic evaluation of an investment project can take many forms. For the Quantum Tech hazardous materials processing plant, the following four techniques or criteria were utilized to evaluate the economicstrength and viability.

1. Net Present Value
2. Internal Rate of Return
3. Payback Period
4. Profitability Index

NET PRESENT VALUE (NPV)

The present value evaluation method compares the present value of future cash flows expected from the investment project to the initial cash outflow attributable directly to the investment. Net cash inflows are defined as the difference between projected cash inflow received as a result of the investment and expected cash outflow of the investment. Net Present Value (NPV) is calculated as follows:

$$NPV = PV - CI$$

where:
CI = Cash outflow resulting from the cost of the investment
PV = Present value = $R_1 \div (1 + i) + R_2 \div (1 + i)^2 + ... R_a \div (1 + i)^a$
R_a = Projected cash flow of the nth period
i = Interest factor @ the incremental cost of capital (ICC)

The generally accepted economic criteria is: If the Net Present Value is positive (NPV>0), then the proposal is a good candidate for investment.

The NPV for the Quantum Tech Project was calculated and is presented in the following tabular format. The initial capital investment is $10,000,000 during the first year. The incremental cost of capital is assumed to be 12% to provide a conservative basis.

NPV OF PROJECTED NET CASH INFLOWS

End of Year	Net Cash Inflows	IF, at ICC	Present Values Inflow	Outflow	NPV
0		1.0000		-10,000,000	- 10,000,000
1	12,654,824	0.8929	11,299,492		11,299,492
2	16,867,765	0.7972	13,446,982		13,446,982
3	21,154,463	0.7118	15,057,747		15,057,747
			39,804,221	-10,000,000	29,804,221

Conclusion: The Quantum Tech Project investment is projected to result in a Net Present Value of $ 29,804,221, therefore, this significant positive value indicates a very good investment.

ECONOMIC EVALUATION - HAZARDOUS MATERIALS' PLANT

INTERNAL RATE OF RETURN (IRR)

The Internal Rate of Return (IRR) refers to the yield or interest rate that equates present value of expected cash flows from an investment to the cost of the investment. IRR is determined by setting the Net Present Value (NPV) equal to zero, as shown in the following formula:

$$NPV = [R_1 \div (1 + IRR) + ... R_n \div (1 + IRR)^n] - CI = \underline{0}$$

In calculating NPV, the number of periods involved (n), cash flows for each period (R), timing of cash flows, discount interest rate (i), and cost of the investment (CI) are projected or known. In calculating IRR, NPV is no longer treated as unknown, but is set equal to zero and the interest rate is now unknown. This means the calculation of IRR becomes a trial-and-error process.

With this economic evaluation method, IRR must be greater than or equal to the incremental cost of capital (ICC) in order for the project to be a good candidate for investment.

The IRR for the Quantum Tech Project was calculated using the same basis as the NPV computation with the incremental cost of capital at 12%. The IRR trial-and-error solutions are presented in the following tabular form:

CALCULATION OF THE IRR

End of Year	Cash Flow	IF_p = 50%	NPV	IF_p = 100%	NPV
0	- 10,000,000	1.0000	-10,000,000	1.0000	- 10,000,000
1	12,654,824	0.6667	8,436,971	0.5000	6,327,412
2	16,867,765	0.4444	7,496,035	0.2500	4,216,941
3	21,154,463	0.2963	6,268,067	0.1250	2,644,308
			12,201,073		3,188,661

End of Year	Cash Flow	IF_p = 135%	NPV	IF_p = 136%	NPV
0	- 10,000,000	1.0000	- 10,000,000	1.0000	- 10,000,000
1	12,654,824	0.4255	5,384,628	0.4237	5,361,849
2	16,867,765	0.1811	3,054,752	0.1795	3,027,764
3	21,154,463	0.0771	1,631,009	0.0761	1,609,855
			70,389		- 532

Conclusion: When the discount interest rate is set equal to 136%, NPV equals just - $532, which is sufficiently close to zero (0) in this case. Since the incremental cost of capital was assumed to be 12%, the IRR of 136% is more than eleven times the ICC. Therefore, the Quantum Tech Project is an excellent candidate for capital investment.

ECONOMIC EVALUATION - HAZARDOUS MATERIALS' PLANT

PAYBACK PERIOD (PB)

The Payback method focuses on the Payback Period (PB), which is defined as the amount of time it takes to recover the initial capital investment. When the annual cash flows are constant and of equal amounts, the PB is calculated by the simple formula:

$$PB = CI \div R$$
$$\text{where: } CI = \text{Cost of the investment}$$
$$R = \text{Net cash inflow in the period}$$

When the periodic cash flows are not equal as in the Quantum Tech Project, the calculation of Payback is more complex. One caution related to the Payback method is that it works with undiscounted amounts so it ignores entirely the time value of money. The net cash flows for Quantum are taken from the Projected Financials based on the initial capital investment of $10,000,000.

End of Year	Cash Flows	Undiscounted Investment Balance To Be Recovered
0	- 10,000,000	- 10,000,000
1	12,654,824	+ 2,654,324
2	16,867,765	+ 19,522,589
3	21,154,463	+ 40,677,052

Conclusion: The Quantum Tech Project with a Payback Period of 0.79 years (approximately ten months) is a good investment opportunity.

PROFITABILITY INDEX (PI)

The Profitability Index uses the same variables as NPV, but combines them differently. PI is defined as follows:

$$PI = PV \div CI$$
$$\text{where: } PV = \text{Present value}$$
$$CI = \text{Cost of the investment}$$

Using the previously calculated PV, the Profitability Index is:

$$PI = 50,677,052 \div 10,000,000 = \underline{5.07}$$

If the PI is greater than 1.0, then the project is a good candidate for investment.

Conclusion: Since the PI is greater than 1.0, the Quantum Tech Project is a good candidate for investment.

Quantum Tech. Inc. - Projected Financials

HAZARDOUS/NON-HAZARDOUS MATERIALS DESTRUCTION PLANT

	Year 1	Year 2	Year 3
Materials Processed, gallons	12,960,000	13,089,600	13,219,200
Average Processing Price, $ per gal.	2.00	2.50	3.00
Gross Revenues, $	25,920,000	32,724,000	39,657,600
Cost of Goods Sold, $ (Labor, Utilities, Insurance, PR OHs)	3,176,640	3,335,472	3,502,246
Operating Profit, $	22,743,360	29,388,528	36,155,354
Operating Profit as % of Sales	88%	90%	91%
General/Administration Expenses, $	3,274,400	3,438,120	3,610,026
Gross Profit, $	19,468,960	25,950,408	32,545,328
Federal Income Tax @ 35%, $	6,814,136	9,082,643	11,390,865
Net Profit, $	12,654,824	16,867,765	21,154,463
Debt Service/Principal Payments, $	3,333,343	3,333,343	3,333,343
Net Profit for Reinvestment, $	9,321,481	13,534,422	17,821,120

Probable Future Cash Flows For Year 3

Year	m = 1	m = 2	m = 3	m = 4	m = 5
3	8,433,883	12,650,824	16,867,765	16,867,765	16,867,765

Basis: m = 1: Assume Plant operates at 50% capacity and processing charge is $2.50 per gal.
m = 2: Assume Plant operates at 75% capacity and processing charge is $2.50 per gal.
m = 3: Assume Plant operates at 100% capacity and processing charge is $2.50 per gal.
m = 4: Same as m=3, operation at 100% capacity and $2.50 per gal.
m = 5: Same as m=3, operation at 100% capacity and $2.50 per gal.

It is also assumed the probabilities of occurrence do not change from one year to the next. As a result the probability of occurrence for the mth cash flows are: $Pm = .1$ for m_1; $Pm = .2$ for m_2; $Pm = .4$ for m_3; $Pm = .2$ for m_4; and $Pm = .1$ for m_5.

The calculation of the expected values of the future cash flows, $E(R_{1,2,3})$ for each of the three years is shown in the following tabular format:

Expected Values of Future Cash Flows For Years 1, 2, 3

m	Pm	R_1 m	R_1 Pm	R_2 m	R_2 Pm	R_3 m	R_3 Pm
1	.1	24,616	2,462	6,327,412	632,741	8,433,883	843,388
2	.2	2,157,514	431,503	8,442,824	1,688,565	12,650,824	2,530,165
3	.4	4,295,914	1,718,366	12,654,824	5,061,930	16,867,765	6,747,130
4	.2	4,295,914	859,183	12,654,824	2,530,965	16,867,765	3,373,565
5	.1	4,295,914	429,591	12,654,824	1,262,482	16,867,765	1,686,782
			$E(R_1)$ 3,441,105		$E(R_2)$ 11,179,683		$E(R_3)$ 15,181,030

Next, the expected present values (PV) and expected net present values (NPV) are calculated as follows:

Expected Value of The Present Value and Net Present Value of Future Cash Flows

End of Year	$E(R_n)$	IF$_p$ @ 12%	EV of PV
1	3,441,105	0.8929	3,072,563
2	11,179,683	0.7972	8,912,443
3	15,181,030	0.7118	10,805,857
		E(PV)	22,790,863

Then, the expected net present value, $E(NPV) = E(PV) - CI$

$$= 22,790,863 - 10,000,000$$

$$E(NPV) = 12,790,863$$

ECONOMIC RISK ANALYSIS - QUANTUM TECH HAZ MAT PLANT

The average dispersion of individual cash flows, Rm, around the expected value of cash flows, known as the variance is determined by the following formula:

$$Var(R) = E\,[(R_m - E(R_n))]^2\,Pm$$

where: R_m = The mth value of cash flow
         $E(R_n)$ = Expected value of cash flow during the nth period
         Pm = Probability of occurrence of R_m

The standard deviation of the future cash flows is defined as:

$$SD[Var(R)] = \sqrt{Var(R)}$$

NOTE: The Standard Deviation is considered a measure of absolute risk in that, the higher the Standard Deviation, the greater the risk.

The variances and standard deviations of the future cash flows were calculated as follows:

1ST YEAR

m	$R_{1m} - E(R_1)$	$[R_{1m} - E(R_1)]^2$	P_{1m}	$[R_{1m} - E(R_1)]^2\,P_{1m}$
1	24,616 - 3,441,105	11.67×10^{12}	.1	1.17×10^{12}
2	2,157,514 - 3,441,105	1.65×10^{12}	.2	0.33×10^{12}
3	4,295,914 - 3,441,105	3.44×10^{12}	.4	1.38×10^{12}
4	4,295,914 - 3,441,105	3.44×10^{12}	.2	0.69×10^{12}
5	4,295,914 - 3,441,105	3.44×10^{12}	.1	0.34×10^{12}

$$Var(R_1) = 3.91 \times 10^{12}$$

Then, the Standard Deviation $SD[Var(R_1)] = \sqrt{3,910,000,000,000}$ = **$1,977,372**

The variances and standard deviations for Years 2 and 3 were calculated in the same manner, with the following results:

	1st Year	2nd Year	3rd Year
Variance in cash flow, $Var(R_n)$	3.91×10^{12}	5.39×10^{12}	7.83×10^{12}
Standard Deviation, $SD[Var(R_n)]$	1,977,372	2,321,677	2,798,214

The formula for the calculation of the variance of the Net Present Value, Var(NPV), of an investment project with independent probable cash flows for a number of future years is:

$$Var(NPV) = [\,Var(R_1) \times 1/(1+i)^2 + Var(R_2) \times 1/(1+i)^4 + \ldots Var(R_n) \times 1/(1+i)^{2n}\,]$$

Then, the Standard Deviation of the Var(NPV) = $\sqrt{Var(NPV)}$

ECONOMIC RISK ANALYSIS - QUANTUM TECH HAZ MAT PLANT

The calculation of the variance in Net Present Value, Var(NPV), and the Standard Deviation, SD(NPV), are shown in the following table:

n Year	$Var(R_n)$	$1/(1+i)^{2n}$	$Var(R_n) \times 1/(1+i)^{2n}$
1	3.91×10^{12}	0.7972	3.12×10^{12}
2	5.39×10^{12}	0.6355	3.43×10^{12}
3	7.83×10^{12}	0.5066	3.97×10^{12}
		$Var(NPV) =$	10.52×10^{12}

The Standard Deviation, $SD(NPV) = \sqrt{10,520,000,000,000} = \$3,243,455$

The relative risk, also known as the Coefficient of Variation, CV(NPV), is defined as the ratio of the standard deviation of the net present value, SD(NPV) to the expected value of the net present value, E(NPV) of the investment:

$$CV(NPV) = SD(NPV) / E(NPV)$$
$$CV(NPV) = 3,892,300 / 12,790,863$$
$$CV(NPV) = \underline{0.304}$$

Conclusions: The Quantum Tech hazardous waste processing plant has an acceptable level of economic risk based on the factors evaluated. It is apparent, the primary factors influencing economic risk will be:

* Securing commitments for the continuous supply of hazardous waste raw materials to insure the plant operates at 100% capacity, i.e., 180 tons per day (36,000 gallons) for 360 days annually.
* Ability to charge processing fees of $2.00 per gallon ($400 per ton) or higher.

As can be seen in this risk analysis, when the plant operation is reduced to 50 - 75% capacity (Years 1,2,3) and processing fees are only $1.00 per gallon (Year 1), the effect on the four criteria utilized to evaluate the overall economic strength and viability is as follows:

1. The projected Net Present Value, NPV, decreases from $29,804,221 to $12,790,863.
2. The Internal Rate of Return, IRR, is reduced from 136% to 61.5%.
3. The projected Payback Period, PB, increases from 0.79 years to 1.59 years.
4. The Profitability Index, PI, decreases from 5.07 to 2.98.

Even with these lower indicator values, the Quantum Tech Project still is an attractive investment opportunity.

ECONOMIC EVALUATION - METHANOL PRODUCTION PLANT

INTRODUCTION

The overall economic evaluation of an investment project can take many forms. For the Quantum Tech Methanol production plant, the following four techniques or criteria were utilized to evaluate the economic strength and viability.

1. Net Present Value
2. Internal Rate of Return
3. Payback Period
4. Profitability Index

NET PRESENT VALUE (NPV)

The present value evaluation method compares the present value of future cash flows expected from the investment project to the initial cash outflow attributable directly to the investment. Net cash inflows are defined as the difference between projected cash inflow received as a result of the investment and expected cash outflow of the investment. Net Present Value (NPV) is calculated as follows:

$$NPV = PV - CI$$

where: CI = Cash outflow resulting from the cost of the investment

PV = Present value = $R_1 \div (1 + i) + R_2 \div (1 + i)^2 + ... R_a \div (1 + i)^a$

R_a = Projected cash flow of the nth period

i = Interest factor @ the incremental cost of capital (ICC)

The generally accepted economic criteria is: If the Net Present Value is positive (NPV>0), then the proposal is a good candidate for investment.

The NPV for the Quantum Tech Methanol Plant was calculated and is presented in the following tabular format. The initial capital investment is $10,000,000 during the first year. The incremental cost of capital is assumed to be 12% to provide a conservative basis.

NPV OF PROJECTED NET CASH INFLOWS

End of Year	Net Cash Inflows	IF, at ICC	Present Values Inflow	Outflow	NPV
0		1.0000		-10,000,000	- 10,000,000
1	14,280,422	0.8929	12,750,989		12,750,989
2	15,196,832	0.7972	12,114,914		12,114.914
3	16,157,920	0.7118	11,501,207		11,501,207
			36,367,110	-10,000,000	26,367,110

Conclusion: The Quantum Tech Methanol Plant investment is projected to result in a Net Present Value of $ 26,367,110, therefore, this significant positive value indicates a very good investment.

ECONOMIC EVALUATION - METHANOL PRODUCTION PLANT

INTERNAL RATE OF RETURN (IRR)

The Internal Rate of Return (IRR) refers to the yield or interest rate that equates present value of expected cash flows from an investment to the cost of the investment. IRR is determined by setting the Net Present Value (NPV) equal to zero, as shown in the following formula:

$$NPV = [R_1 \div (1+IRR) + ... R_n \div (1+IRR)^n] - CI = \underline{0}$$

In calculating NPV, the number of periods involved (n), cash flows for each period (R), timing of cash flows, discount interest rate (i), and cost of the investment (CI) are projected or known. In calculating IRR, NPV is no longer treated as unknown, but is set equal to zero and the interest rate is now unknown. This means the calculation of IRR becomes a trial-and-error process.

With this economic evaluation method, IRR must be greater than or equal to the incremental cost of capital (ICC) in order for the project to be a good candidate for investment.

The IRR for the Quantum Tech Methanol Plant was calculated using the same basis as the NPV computation with the incremental cost of capital at 12%. The IRR trial-and-error solutions are presented in the following tabular form:

CALCULATION OF THE IRR

End of Year	Cash Flow	$IF_p = 100\%$	NPV	$IF_p = 130\%$	NPV
0	- 10,000,000	1.0000	-10,000,000	1.0000	- 10,000,000
1	14,280,422	0.5000	7,140,211	0.4348	6,208,879
2	15,196,832	0.2500	3,799,208	0.1890	2,872,201
3	16,157,920	0.1250	<u>2,019,740</u>	0.0822	<u>1,328,181</u>
			<u>2,959,159</u>		<u>409,261</u>

End of Year	Cash Flow	$IF_p = 135\%$	NPV	$IF_p = 136\%$	NPV
0	- 10,000,000	1.0000	- 10,000,000	1.0000	- 10,000,000
1	14,280,422	0.4255	6,076,319	0.4237	6,050,615
2	15,196,832	0.1811	2,752,146	0.1795	2,727,831
3	16,157,920	0.0771	<u>1,245,776</u>	0.0761	<u>1,229,618</u>
			<u>74,241</u>		<u>8,064</u>

Conclusion: When the discount interest rate is set equal to 136%, NPV equals just $8,064, which is sufficiently close to zero (0) in this case. Since the incremental cost of capital was assumed to be 12%, the IRR of 136% is more than eleven times the ICC. Therefore, the Quantum Tech Methanol Plant is an excellent candidate for capital investment.

ECONOMIC EVALUATION - METHANOL PRODUCTION PLANT

PAYBACK PERIOD (PB)

The Payback method focuses on the Payback Period (PB), which is defined as the amount of time it takes to recover the initial capital investment. When the annual cash flows are constant and of equal amounts, the PB is calculated by the simple formula:

$$PB = CI \div R$$
where: CI = Cost of the investment
R = Net cash inflow in the period

When the periodic cash flows are not equal as in the Quantum Tech Methanol Plant, the calculation of Payback is more complex. One caution related to the Payback method is that it works with undiscounted amounts so it ignores entirely the time value of money. The net cash flows are taken from the Projected Financials based on the initial capital investment of $10,000,000.

End of Year	Cash Flows	Undiscounted Investment Balance To Be Recovered
0	- 10,000,000	- 10,000,000
1	14,280,422	+ 4,280,422
2	15,196,832	+ 19,477,254
3	16,157,920	+ 35,635,174

Conclusion: The Quantum Tech Methanol Plant with a Payback Period of 0.70 years (approximately nine months) is a good investment opportunity.

PROFITABILITY INDEX (PI)

The Profitability Index uses the same variables as NPV, but combines them differently. PI is defined as follows:
$$PI = PV \div CI$$
where: PV = Present value
CI = Cost of the investment

Using the previously calculated PV, the Profitability Index is:

$$PI = 45,635,174 \div 10,000,000 = \underline{4.56}$$

If the PI is greater than 1.0, then the project is a good candidate for investment.

Conclusion: Since the PI is greater than 1.0, the Quantum Tech Methanol Plant is a good candidate for investment.

PATENTS

United States Patent [19]

Kulkarni

[11] Patent Number: 5,138,959

[45] Date of Patent: Aug. 18, 1992

[54] **METHOD FOR TREATMENT OF HAZARDOUS WASTE IN ABSENCE OF OXYGEN**

[76] Inventor: **Prabhakar Kulkarni**, 12027 Circle Dr. E., Houston, Tex. 77071

[21] Appl. No.: **693,942**

[22] Filed: **Apr. 29, 1991**

Related U.S. Application Data

[63] Continuation of Ser. No. 471,551, Jan. 29, 1990, Pat. No. 5,010,829, which is a continuation-in-part of Ser. No. 244,318, Sep. 15, 1988, Pat. No. 4,896,614.

[51] Int. Cl.⁵ F23G 7/04
[52] U.S. Cl. 110/346; 110/250; 110/345; 422/186; 423/447.3
[58] Field of Search 423/447.3, 449, 450, 423/461; 110/341, 346, 237, 238, 250; 422/189

[56] **References Cited**

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4,693,879	9/1987	Yoshimura et al.	423/461
4,886,001	12/1989	Chang et al.	110/250 X
4,909,164	3/1990	Shohet	110/346

Primary Examiner—Edward G. Favors
Attorney, Agent, or Firm—Gunn, Lee & Miller

[57] **ABSTRACT**

Hazardous waste treatment method and apparatus are disclosed in the preferred and illustrated embodiment. A feedstock of solid or liquid hazardous waste material is combusted in a plasma generator in the absence of oxygen and converted into non-hazardous components which are collected in a reactor chamber. The non-hazardous components are further converted into a gaseous outflow which is cooled and separated into selected constituents which are collected in storage vessels.
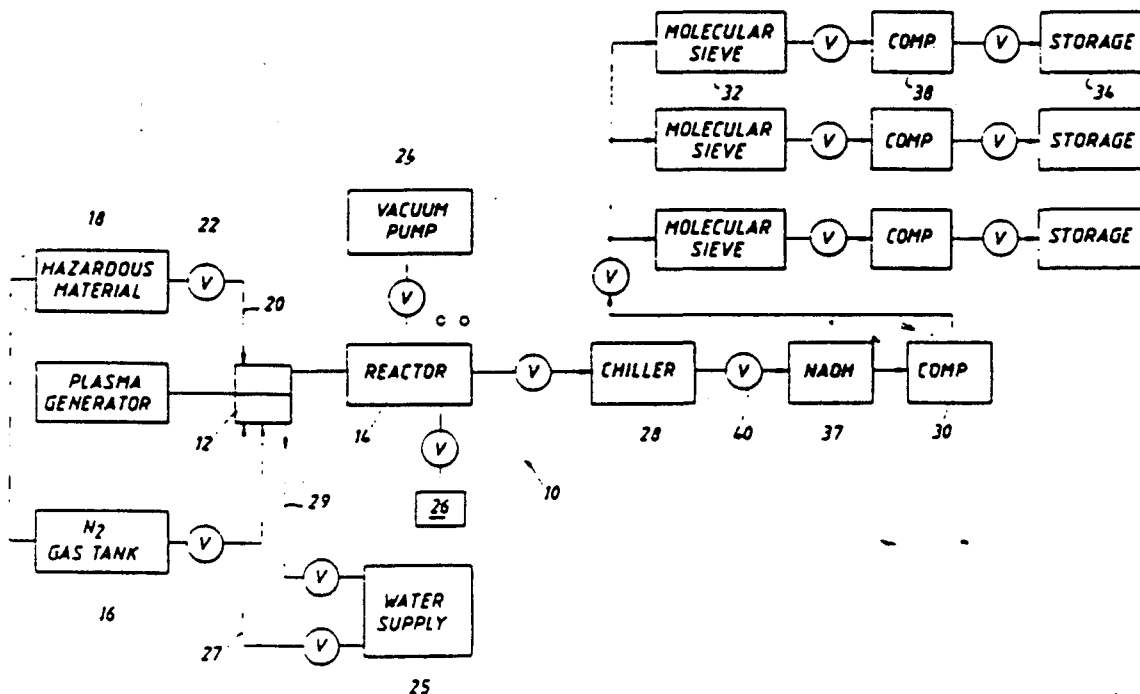
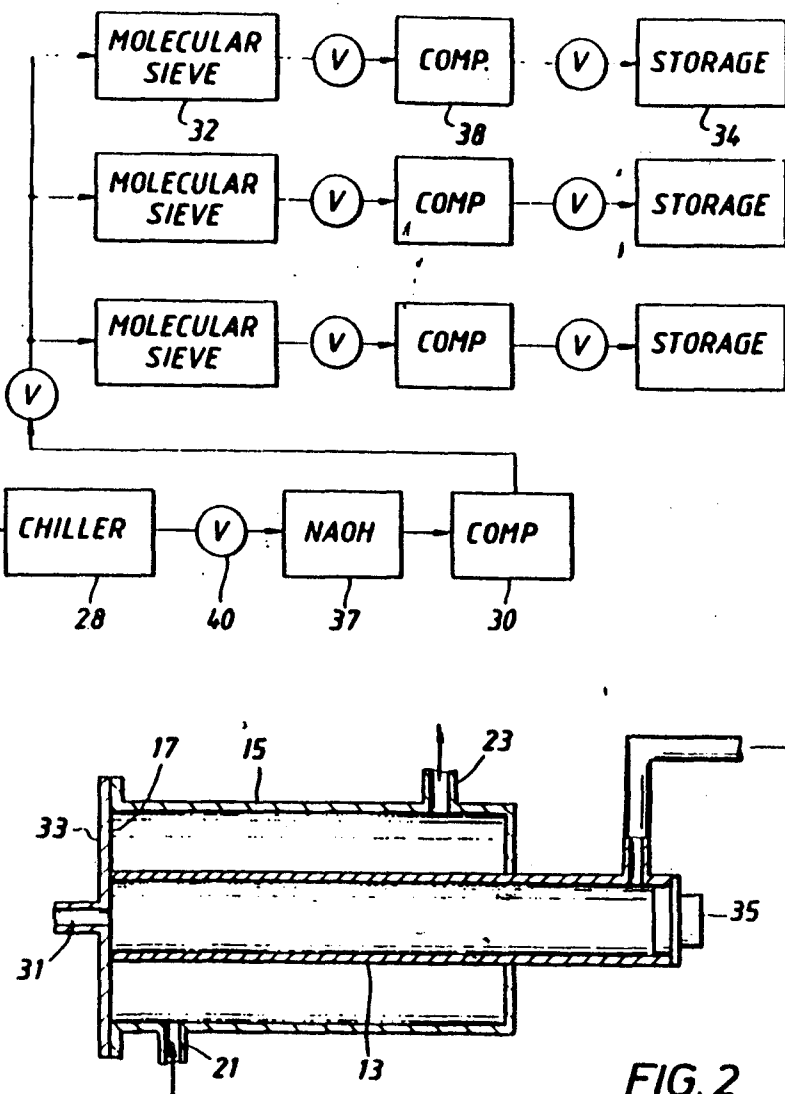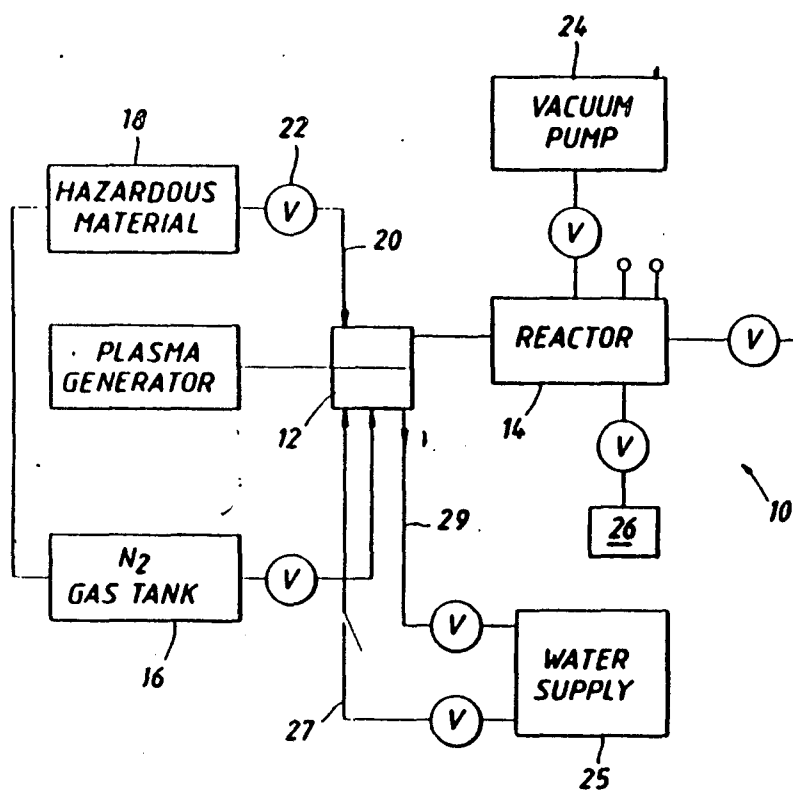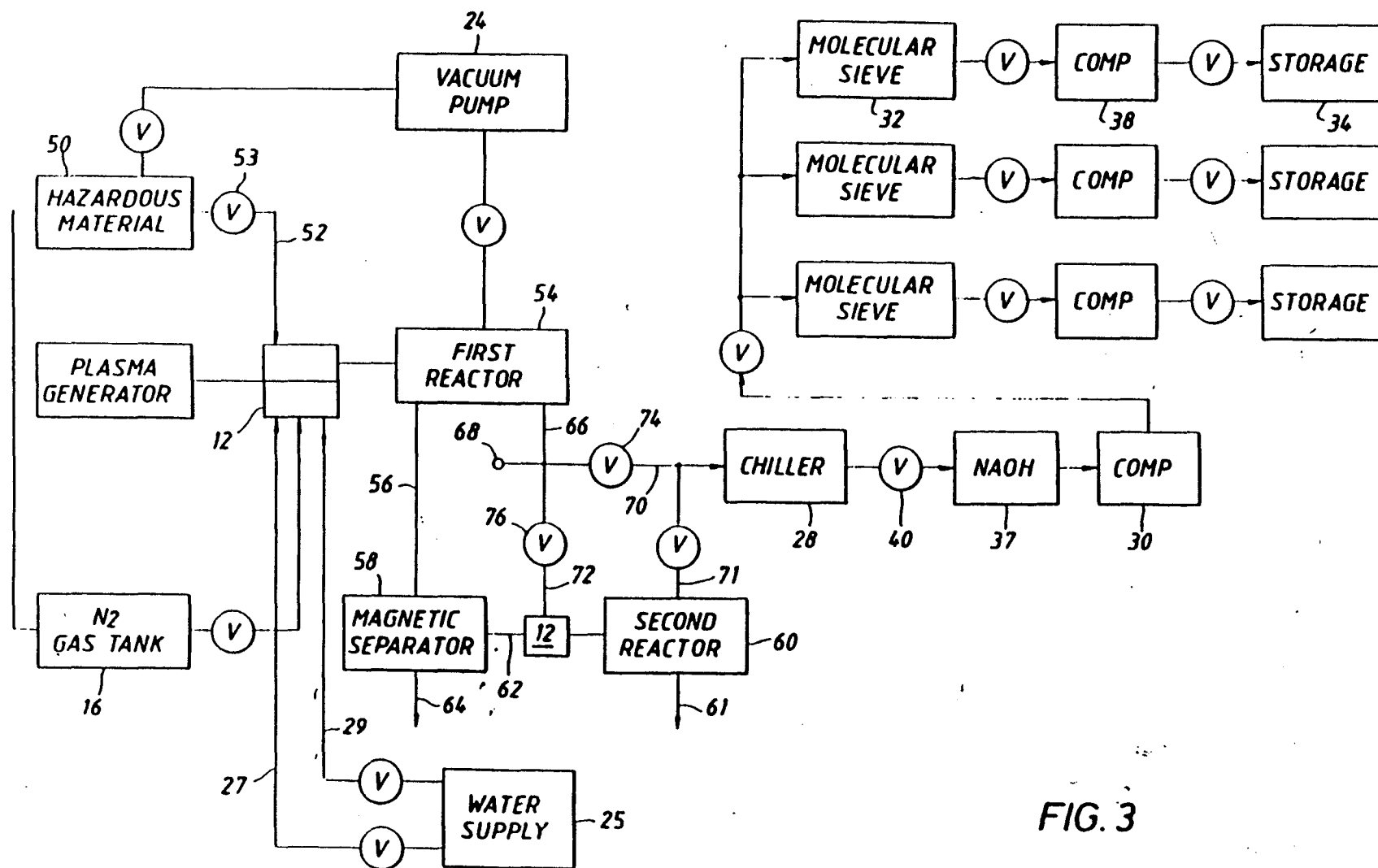**8 Claims, 2 Drawing Sheets**

FIG.1

FIG.2

VACUUM PUMP 24

HAZARDOUS MATERIAL 50

PLASMA GENERATOR

N2 GAS TANK 16

FIRST REACTOR 54

MAGNETIC SEPARATOR 58

SECOND REACTOR 60

WATER SUPPLY 25

MOLECULAR SIEVE 32 — V — COMP 38 — V — STORAGE 34

MOLECULAR SIEVE — V — COMP — V — STORAGE

MOLECULAR SIEVE — V — COMP — V — STORAGE

CHILLER 28 — V 40 — NAOH 37 — COMP 30

12

FIG. 3

US005138959A

United States Patent [19]

Kulkarni

[11] Patent Number: 5,138,959

[45] Date of Patent: Aug. 18, 1992

[54] **METHOD FOR TREATMENT OF HAZARDOUS WASTE IN ABSENCE OF OXYGEN**

[76] Inventor: Prabhakar Kulkarni, 12027 Circle Dr. E., Houston, Tex. 77071

[21] Appl. No.: 693,942

[22] Filed: Apr. 29, 1991

Related U.S. Application Data

[63] Continuation of Ser. No. 471,551, Jan. 29, 1990, Pat. No. 5,010,829, which is a continuation-in-part of Ser. No. 244,318, Sep. 15, 1988, Pat. No. 4,896,614.

[51] Int. Cl.⁵ F23G 7/04
[52] U.S. Cl. 110/346; 110/250; 110/345; 422/186; 423/447.3
[58] Field of Search 423/447.3, 449, 450, 423/461; 110/341, 346, 237, 238, 250; 422/189

[56] References Cited

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4,592,007 9/1985 Murray 423/450
4,688,495 8/1987 Galloway .... 110/237 X
4,693,879 9/1987 Yoshimura et al. 423/461
4,886,001 12/1989 Chang et al. .... 110/250 X
4,909,164 3/1990 Shohet 110/346

Primary Examiner—Edward G. Favors
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[57] **ABSTRACT**

Hazardous waste treatment method and apparatus are disclosed in the preferred and illustrated embodiment. A feedstock of solid or liquid hazardous waste material is combusted in a plasma generator in the absence of oxygen and converted into non-hazardous components which are collected in a reactor chamber. The non-hazardous components are further converted into a gaseous outflow which is cooled and separated into selected constituents which are collected in storage vessels.
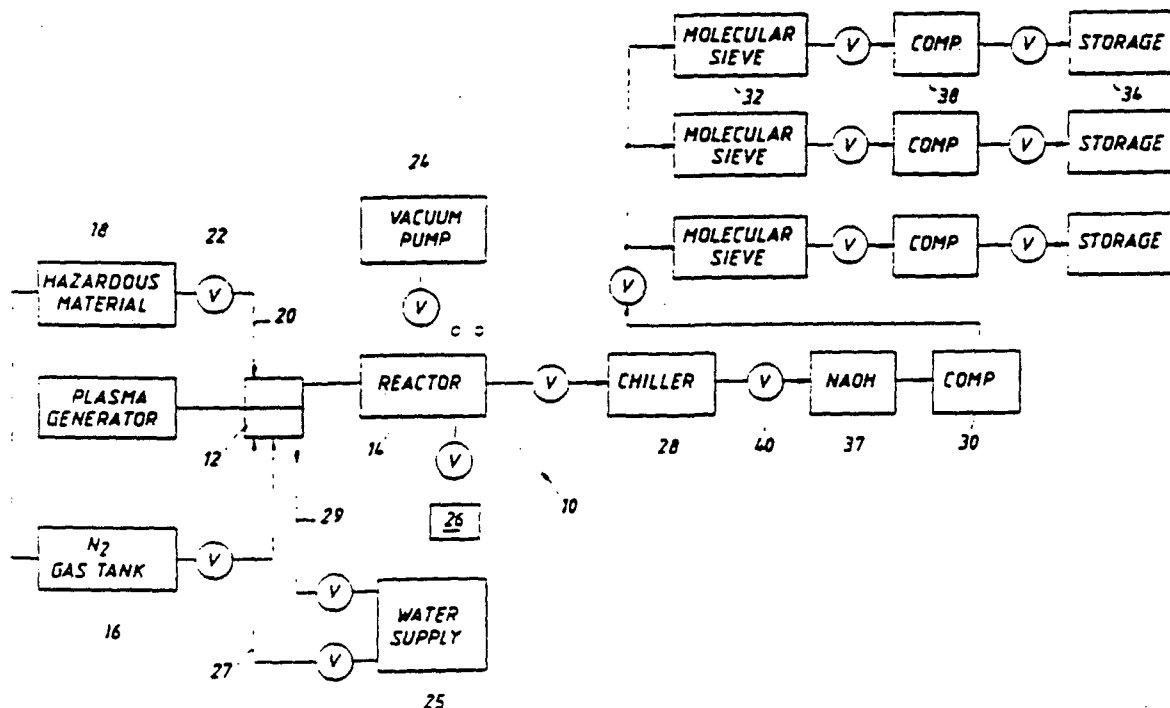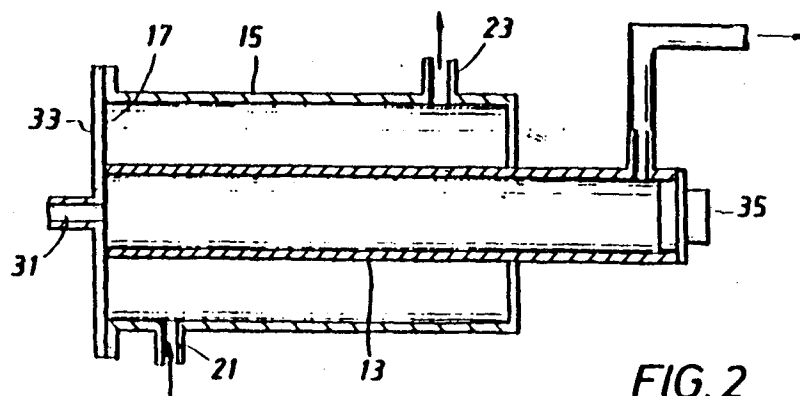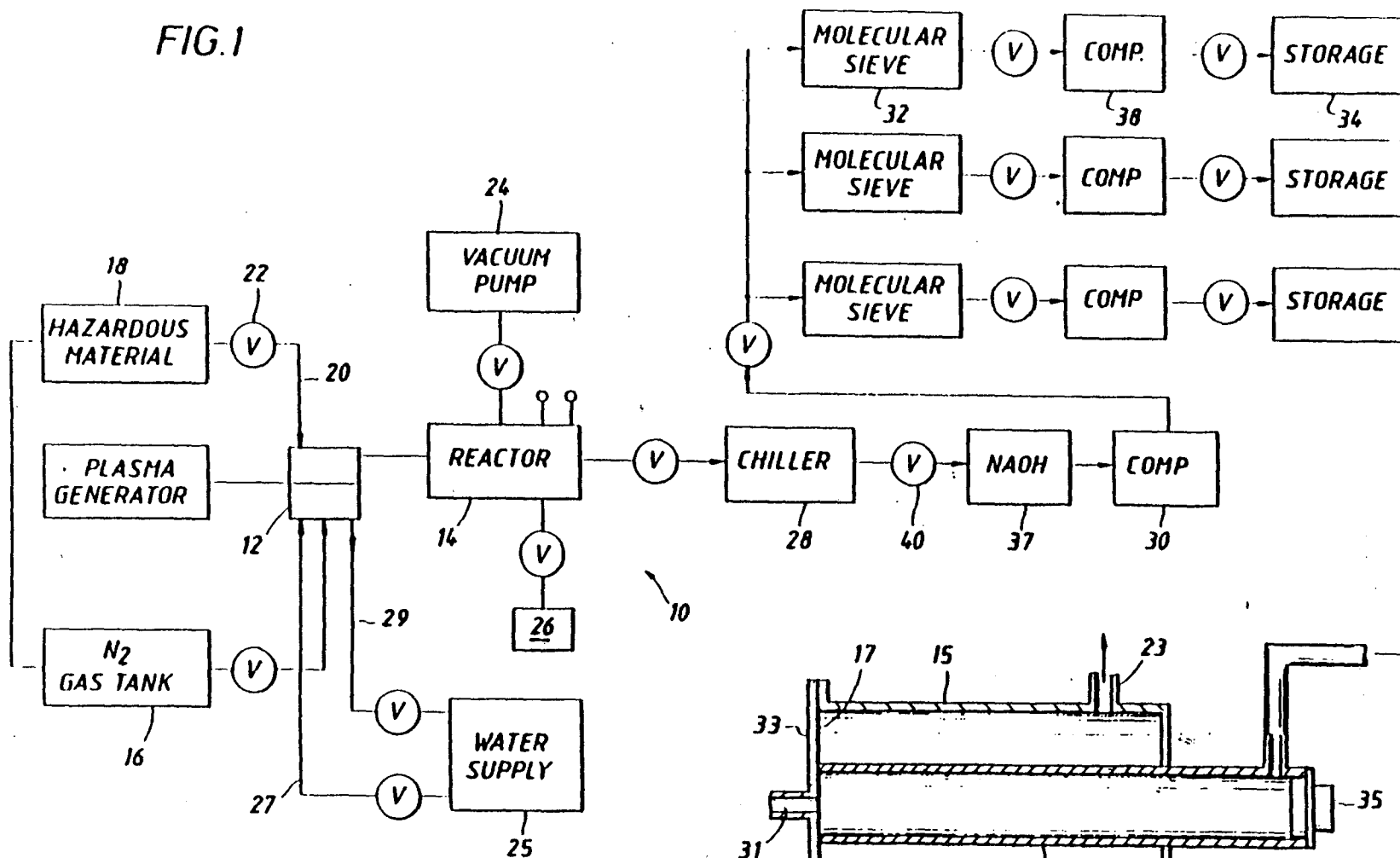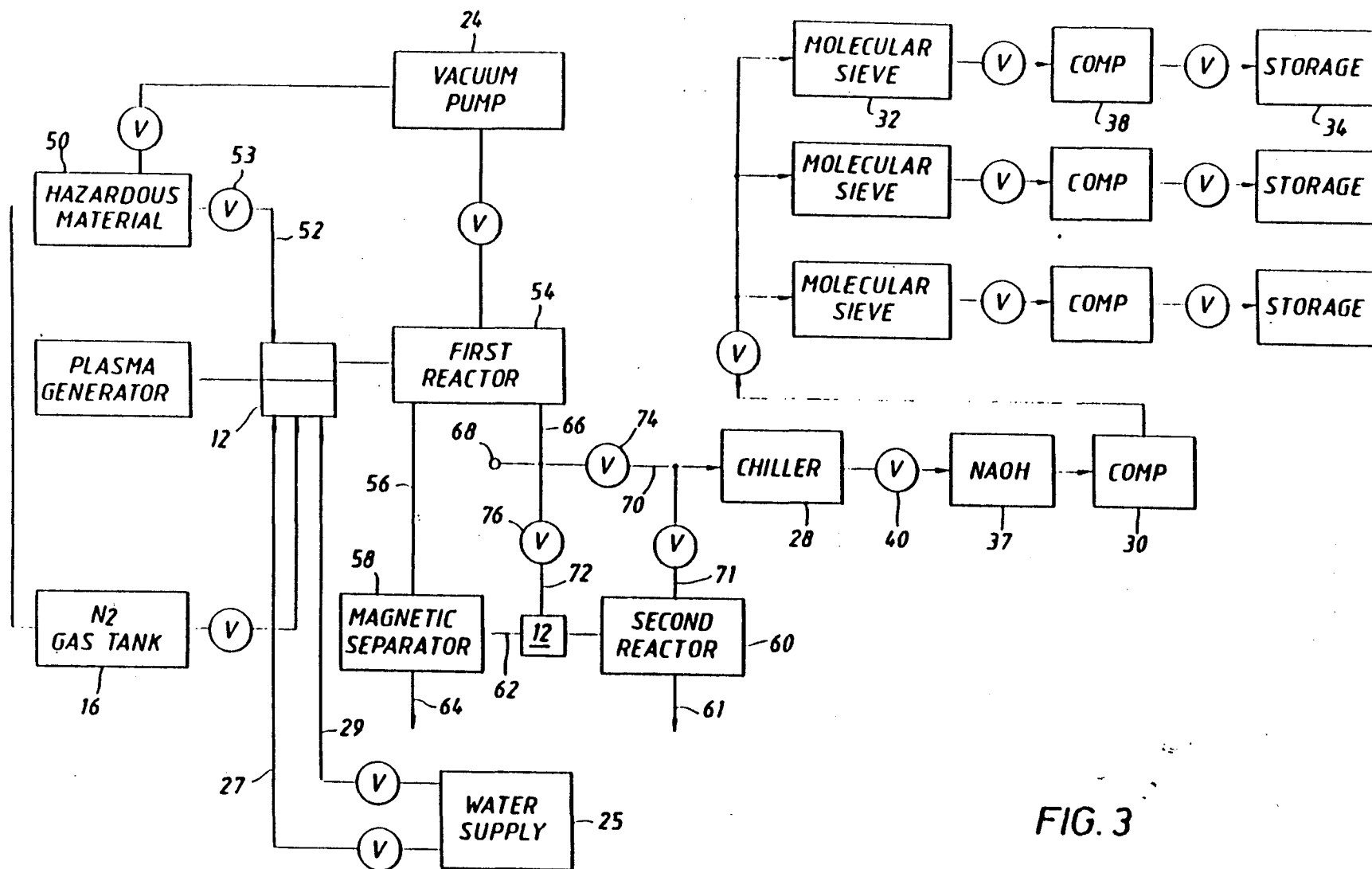
8 Claims, 2 Drawing Sheets

FIG.1

MOLECULAR SIEVE — 32
V
COMP. — 38
V
STORAGE — 34

MOLECULAR SIEVE
V
COMP
V
STORAGE

MOLECULAR SIEVE
V
COMP
V
STORAGE

24
VACUUM PUMP

18
HAZARDOUS MATERIAL
22
V
20

PLASMA GENERATOR

12

16
N₂ GAS TANK
V

29

27

V

25
WATER SUPPLY

14
REACTOR
V

26
V

V

10

V
CHILLER
28
V
40
NAOH
37
COMP
30

FIG. 2

17   15   23
33
31
21   13
35

FIG. 3

METHOD FOR TREATMENT OF HAZARDOUS WASTE IN ABSENCE OF OXYGEN

RELATED APPLICATIONS

This is a continuation of Application Ser. No. 07/471,551 filed Jan. 29, 1990, now U.S. Pat. No. 5,010,829, issued on Apr. 30, 1991, which is a continuation-in-part of application Ser. No. 07/244,318 filed Sep. 15, 1988, now U.S. Pat. No. 4,896,614, issued on Jan. 30, 1990.

BACKGROUND OF THE DISCLOSURE

This invention relates to the destruction of hazardous waste materials, particularly, to a method and apparatus for conversion of hazardous waste material into useful by-products.

The safe disposal of hazardous waste materials is a high priority for both private industry and governmental agencies. A superfund has been established by the government to clean up areas of hazardous waste which present eminent danger to the public health and welfare. Thousands of regulations have been promulgated by the government to insure the safe use and disposal of hazardous materials. Use of some hazardous materials has been banned or extremely restricted. Due to the severity of the problem, various methods have been utilized for disposing of hazardous materials. Research continues in an effort to develop a method for the destruction of hazardous material which is also environmentally safe.

Various methods have been attempted for the disposal of hazardous material, including the use of electric plasma arcs to destroy toxic waste. Plasma generators are known in the prior art. A plasma arc generated by a plasma gun develops an extremely hot temperature zone having temperatures in the range of 10,000° F. to 30,000° F., or above. At such high temperatures, almost all organic and inorganic compounds may be converted into useful by-products.

U.S. Pat. No. 4,644,877 discloses a method and apparatus for the pyroelectric destruction of toxic or hazardous waste materials. The waste materials are fed into a plasma arc burner where they are atomized and ionized, and then discharged into a reaction chamber to be cooled and recombined into product gas and particulate matter. The recombined products are quenched using a spray ring attached to the reaction vessel. An alkaline atomized spray produced by the spray ring neutralizes the recombined products and wets the particulate matter. The product gases are then extracted from the re-combining of products using a scrubber, and the product gases are then burned or used for fuel.

U.S. Pat. No. 4,479,443 discloses a method and apparatus for thermal decomposition of stable compounds. High temperatures necessary for decomposition are generated by a plasma generator. U.S. Pat. Nos. 4,438,706 and 4,509,434 disclose a procedure and equipment for destroying waste material. The material is decomposed in a plasma state in the presence of an oxidizing agent so that the waste material is converted into stable combustion products.

U.S. Pat. No. 4,615,285 discloses a method of destroying hazardous waste by means of under-stoichiometric incineration at a temperature of at least 1,200° C. The ratio between injected waste material and oxidant is regulated to give a quotient $CO_2/(CO - CO_2)$ of less than 0.1.

U.S. Pat. Nos. 4,602,991 and 4,729,891, by the Applicant herein disclose a coal liquefaction process and hydrogen generating method, respectively, wherein the feed stock is heated in an inductive furnace under vacuum conditions.

As is noted above, various methods have been tried for disposing of hazardous waste material. Until the present invention, however, a commercially viable process which combines vacuum, induction and plasma technology for conversion of hazardous materials into useful by-products has not been available.

SUMMARY OF THE INVENTION

The present invention is directed to a method of destroying hazardous waste material, both liquid and solid waste material. The method comprises the steps of converting the hazardous material by exposing it to at least one high temperature plasma arc in the absence of oxygen. The converted gases and any non-gaseous constituents are collected in a depressurized reactor chamber which is devoid of oxygen. Solid waste material is directed through two reaction chambers. The collected gases are then directed through a series of chillers, compressors and molecular sieves for separation of the gases into individual components. The separated components are collected in storage vessels. None of the by-products of the process of the invention are released into the atmosphere.

DETAILED DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features, advantages and objects of the present invention are attained and can be understood in detail, more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

FIG. 1 is a schematic flow diagram of a method of treating hazardous waste material in the absence of oxygen;

FIG. 2 is a partial sectional view of the plasma generator of the invention; and

FIG. 3 is a schematic flow diagram of a method of treating solid hazardous waste material in the absence of oxygen.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1, the system of the invention for treatment of hazardous waste material is generally identified by the reference numeral 10. The system 10 includes a plasma generator 11 and plasma gun 12 connected to a reactor chamber 14. The plasma gun 12 is of a type commercially available. The plasma gun 12 is connected to a power supply which delivers power to operate the plasma gun 12. The plasma arc generated by the plasma gun 12 is sustained by nitrogen or argon gas which is supplied to the plasma gun 12 from a gas supply 16. Hydrogen may also be supplied to aid the conversion of waste material containing oxygen. The hydrogen will combine with the oxygen to form water. The plasma arc generated by the plasma gun 12 is a high temperature plasma sustaining plasma temperatures in

the range of 10.000° F. to 30,000° F., or higher. At such high temperatures, almost all organic and inorganic compounds are split into individual components. While in the preferred embodiment, a plasma gun 12 generates the required temperatures for converting the waste material, it is understood that sufficiently high temperatures for accomplishing the conversion may be developed by other means, such as lasers or induction heating. The conversion of hazardous material may be accomplished at a temperature of 1,200° F. or above.

A source or feedstock of hazardous material 18 is connected to the plasma gun 12 via a feed line 20. The hazardous material is transported to the plasma gun 12 in a flowing slurry of liquid material through the feed line 20. Alternatively, a screw conveyer may be used to transport solid material to the inlet of the plasma gun 12. In the preferred embodiment, the hazardous material is fed to the plasma gun 12 through the feed line 20 at a predetermined rate of approximately three to six gallons per minute. If desired, the hazardous material may be fed to the plasma gun 12 at higher rates. For example, solid waste may be fed at a rate of up to two tons per hour or more. A valve 22 connects the feed line 20 to the hazardous material 18. The valve 22 may be opened or closed to increase or decrease the flow rate of hazardous material transported through the feed line 20.

A partial sectional view of the plasma gun 12 is shown in FIG. 2. Due to the extremely high temperatures generated by the plasma gun 12, a water bath is used to cool the plasma gun 12. The barrel of the plasma gun 12 comprises an inner tube 13 concentrically positioned within an outer tube 15. The inner tube 13 is approximately seven feet eight inches in length and projects outwardly from the end of the outer tube 15 which is approximately six feet in length. Flange support members 17 are mounted about the inner tube 13 and secured to the ends of the outer tube 15. The support members 17 position the inner tube 13 concentrically within the outer tube 15 and close off the annular space 19 defined therebetween. Water is circulated in the annular space 19 for forming a cooling bath about the inner tube 13. Water is directed into the annular space 19 though a water inlet 21 and exits through a water outlet 23. Water is pumped to the plasma gun 12 from a water source 25 though a water line 27 and returned to the water source 25 through a return line 29 so that continuous water circulation is provided to maintain the plasma gun 12 at a relatively cool temperature.

The forward end of the inner tube 13 is provided with an opening 31. The plasma generator control head 33 is connected to the forward end of the inner tube 13. The electrodes of the plasma generator extend through the opening 31 so that the plasma arc is generated within the inner tube 13. The rear end of the inner tube 13 is closed by a removable plug 35. The plug 35 may be removed permitting inspection of the inner tube 13 for pitting or damage from heat or chemical reaction.

The hazardous waste material is incinerated within the inner tube 13. The waste material is delivered to the inner tube 13 via the line 20 which is connected to the plasma generator control head. The plasma gun 12 is connected to the reactor chamber 14 in a suitable manner. The reactor chamber 14 is maintained under vacuum conditions in the range of 10^{-1} to 10^{-3} torr or any lower attainable vacuum, thereby substantially removing all air from the reactor chamber 14. The reactor chamber 14 is evacuated by vacuum pumps 24 con-

nected thereto. A sample container 26 is connected to the reactor chamber 14 for collecting a sample of the gases collected in the reactor chamber 14. The sample of gases is analyzed to insure that the hazardous material has been completely converted to harmless by-products.

From the reactor chamber 14, the collected gases are directed through a chiller 28 for rapidly cooling the gases and then through a NaOH solution tower 37 for converting any hydrochloric acid gases into sodium chloride (NaCl). A compressor 30 is connected to the outlet end of the NaOH tower 37 for pressurizing and directing the collected gases through a series of molecular sieves to remove undesirable impurities in the constituents forming the gas flow from the reactor chamber 14. The gas flow is separated into its individual constituents which are stored in storage vessels 34. Compressors 38 are connected between the molecular sieves 32 and storage vessels 34 for pressurizing the constituents of the gas flow into the storage vessels 34.

As an example, but in no way limiting the scope of the present disclosure, the individual constituents or by-products of the conversion of hazardous materials include nitrogen, hydrogen, carbon dioxide, methane and any silicate, metallic or any other solid constituents that are not converted into a gaseous by-product. The gaseous constituents are separated by passing the gases through the molecular sieves 32 and collecting the individual constituents in the storage vessels 34. The non-gaseous constituents are collected in the reactor 14 and removed upon completion of the conversion process. The reactor 14 includes an internal screw conveyor or the like for expelling any non-gaseous constituents collected in the reactor 14. The hazardous material is thereby converted into harmless by-products which are captured in the storage vessels 34. The process of the present invention is totally environmentally safe as no emissions are released into the atmosphere.

Referring again to FIG. 1, in operation the system 10 is initially pressurized and visually inspected for leaks and pressure drops. Pressures of 50 psi to 80 psi are maintained for a period of time to insure that the system does not leak. After checking that the vacuum pumps 24 are operating properly, the vacuum valves are opened and a vacuum is pulled throughout the system and isolated between closed valves 22 and 40 insuring that all oxygen in the system between the closed valves 22 and 40 is removed. Upon obtaining a vacuum of a minimum of 10^{-1} torr, the plasma gun 12 is activated. The valve 22 is then opened permitting the hazardous material to be delivered to the plasma gun 12. Initially, the pressure in the hazardous material tank is approximately 50 psi. When the pressure has dropped to 5 psi or less, the hazardous material tank 18 is empty and the valve 22 is shut off. The hazardous material is converted in the plasma arc formed by the plasma generator within the inner tube 13 of the plasma gun 12. The converted gases are collected in the reactor chamber 14. During the conversion of the hazardous material, the pressure in the system 10 increases. The valve 40 however is maintained in the closed position until the system pressure reaches the level of approximately 15 psi. Prior to opening the valve 40, a sample of the converted gases is collected in the sample container 26. The sample container 26 is double valved to separate it from the system 10. The sample of gases is then analyzed to determine whether the hazardous materials have been destroyed. If any traces of hazardous material remains in the sam-

ple. the gases are collected and passed through the plasma generator a second time.

Referring now to FIG. 3, a configuration of the system 10 is shown for treatment of solid hazardous material. The system is substantially the same as shown in FIG. 1 and therefore like reference numerals have been used to identify like components. As shown in FIG. 3, the solid waste material is collected in a collection vessel 50. The solid waste material, for example, tires or the like, is fed to the plasma guns 12 through a feedline or conduit 52 at a predetermined rate of up to two tons per hour or more upon opening a valve 53. A screw conveyor or the like transports the solid hazardous waste material from the collection vessel 50 to the plasma guns 12 via the conduit 52. The plasma guns 12 may be connected in series or may be spaced around a plenum which, when energized, will form a concentrated hot zone through which the solid waste material will flow and be collected in the reactor 54. As was discussed above in relation to the system shown in FIG. 1, a vacuum is pulled by the vacuum pumps 24 insuring that all oxygen in the system shown in FIG. 3 is removed. Once the proper vacuum is achieved, the plasma guns 12 are activated and solid waste material is flowed through the hot zone created by the plasma guns.

As the solid waste material passes through the hot zone, it is converted into non-hazardous components and collected in the reactor 54. At this stage of the process, the collection vessel 54 includes carbon black and disassociated gaseous components of the solid waste material in a non-hazardous states. Also, depending on the composition of the solid waste material passed through the hot zone created by the plasma guns 12, some solids such as metals, cans, or the like may be collected in the reactor 54. While the plasma guns 12 create an extremely hot zone, not all components of the solid waste material stream will be converted into a gaseous effluent. Complete conversion of the solid waste material into a gaseous state is dependent upon the volume and flow rate of solid waste material passing through the temperature zone created by the plasma guns 12.

The carbon black and nonconverted solid components of the hazardous material are collected in the bottom of the reactor 14 and transported via a screw conveyor or the like through line 56 to a magnetic separator 58. In the magnetic separator 58 the carbon black is separated from the metal solids and transported to the reactor 60 via a line 62. The solid metal material such as cans, are released from the magnetic separator through a discharge line 64 to a storage vessel for subsequent recycling or other use.

The disassociated non-hazardous gaseous components of the solid waste material are removed from the reactor 54 via a line 66. A volatile organic compound analyzer 68 is incorporated in the line 66 for analyzing the gas stream discharge from the reactor 54. The gas stream may be discharged directly to the chillers 28 via the line 70 or directed to the reactor 60 via the line 72. Valves 74 and 76 are incorporated in the lines 70 and 72, respectively, for directing the gas stream along the selected path.

Lines 62 and 72 join at the inlet of the vessel 60. The carbon black and gas stream from lines 62 and 72 pass through a second hot zone formed by a plasma gun 12 mounted at the inlet of the reactor 60. The gases and carbon black collected in the reactor 54 are passed through a second high temperature zone to insure that hazardous components in the solid waste material are completely converted into individual non-hazardous by products such as nitrogen, hydrogen, and carbon dioxide which are directed to the chillers 28 via line 71 and subsequently collected in the storage vessels 34 in the manner described above in relation to FIG. 1. The reactor 60 includes an internal screw conveyor or the like for expelling the carbon black collected at the bottom thereof via outlet conduit 61 into storage tanks for subsequent use.

When handling hazardous materials, certain steps must be taken to prevent hazards or mishaps from occurring. In the system 10, all components are fabricated of stainless steel material. The system is completely vacuumed as discussed above and all valves used are vacuum valves. In the event of a malfunction, solenoid valves are connected to an emergency shut off on the plasma generator and are utilized to stop the flow of hazardous material. Two manual valves are also incorporated in the system to shut off the flow of hazardous material in case of electrical failure or the like. Pressure gauges 36 monitor the pressure in the system and high temperature gaskets are used at the connections of various components forming the system. A thermal couple 38 is also incorporated in the system for reading or monitoring temperatures of the gases in the system. All exposed pipe of the system is sprayed with water for maintaining it a relatively low temperature.

While the foregoing is directed to the preferred embodiment of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims which follow.

What is claimed is:

1. A method of converting hazardous waste material into useful by-products, comprising the steps of:

(a) introducing the waste material into a first high temperature zone generated by at least one plasma gun and converting the waste material into a mixture of carbon black, gases and non-converted material;

(b) collecting said mixture in a first reactor chamber in the absence of oxygen for preventing the recombination of said mixture with oxygen;

(c) discharging the carbon black and non-converted material into a separator for separating the non-converted material from the carbon black and collecting said non-converted material for subsequent use;

(d) directing said carbon black through a second high temperature zone into a second reactor chamber for further separation and conversion of hazardous constituents into non-hazardous gases;

(e) directing the gases from said first and second reactor chambers through cooling apparatus for reducing the temperature of said gases; and

(f) collecting said gases in storage vessels.

2. The method of claim 1 including the step of forming a vacuum of at least 10^{-1} torr for removing substantially all the oxygen from the reactor chambers.

3. The method of claim 2 including the step of collecting and analyzing a sample of the gases exiting said first reactor chamber.

4. The method of claim 3 including the step of circulating water about the plasma gun for maintaining a continuous cooling bath about the plasma gun.

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5. The method of claim 1 wherein said carbon black is removed from said second reactor chamber and stored for subsequent use.

6. The method of claim 1 wherein said gases from said first reactor chamber are combined with said carbon black and directed through said second temperature zone.

7. The method of claim 1 wherein said first tempera-

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ture zone is created by a plurality of plasma guns connected in series.

8. The method of claim 1 wherein said first temperature zone is created by a plurality of plasma guns spaced about a plenum.

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United States Patent [19]

Kulkarni

[11] Patent Number: 5,010,829

[45] Date of Patent: Apr. 30, 1991

[54] **METHOD AND APPARATUS FOR TREATMENT OF HAZARDOUS WASTE IN ABSENCE OF OXYGEN**

[76] Inventor: Prabhakar Kulkarni, 12027 Circle Dr. E., Houston, Tex. 77071

[21] Appl. No.: 471,551

[22] Filed: Jan. 29, 1990

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 244,318, Sep. 15, 1988, Pat. No. 4,896,614.

[51] Int. Cl.⁵ F23G 7/04
[52] U.S. Cl. 110/346; 110/250; 110/345; 422/186; 423/447.3
[58] Field of Search 110/341, 346, 237, 238, 110/250, 345; 423/447.3; 422/186

[56] **References Cited**

U.S. PATENT DOCUMENTS

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[57] **ABSTRACT**

Hazardous waste treatment method and apparatus are disclosed in the preferred and illustrated embodiment. A feedstock of solid or liquid hazardous waste material is combusted in a plasma generator in the absence of oxygen and converted into non-hazardous components which are collected in a reactor chamber. The non-hazardous components are further converted into a gaseous outflow which is cooled and separated into selected constituents which are collected in storage vessels.
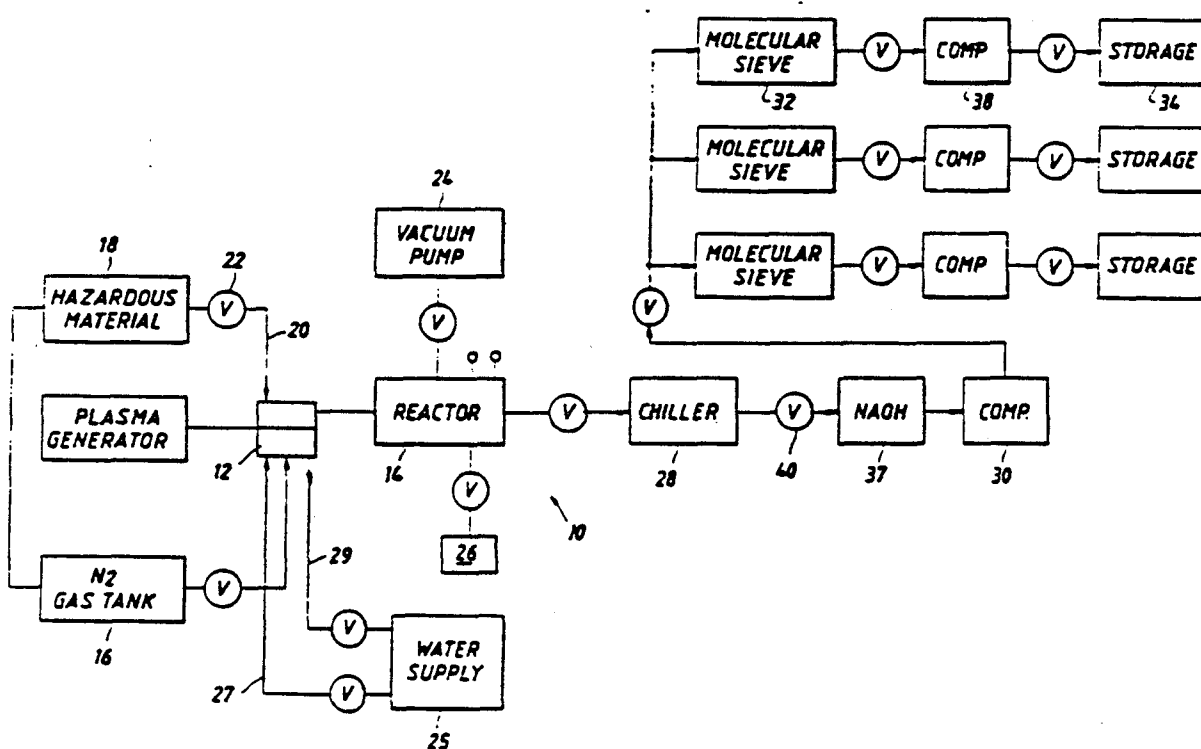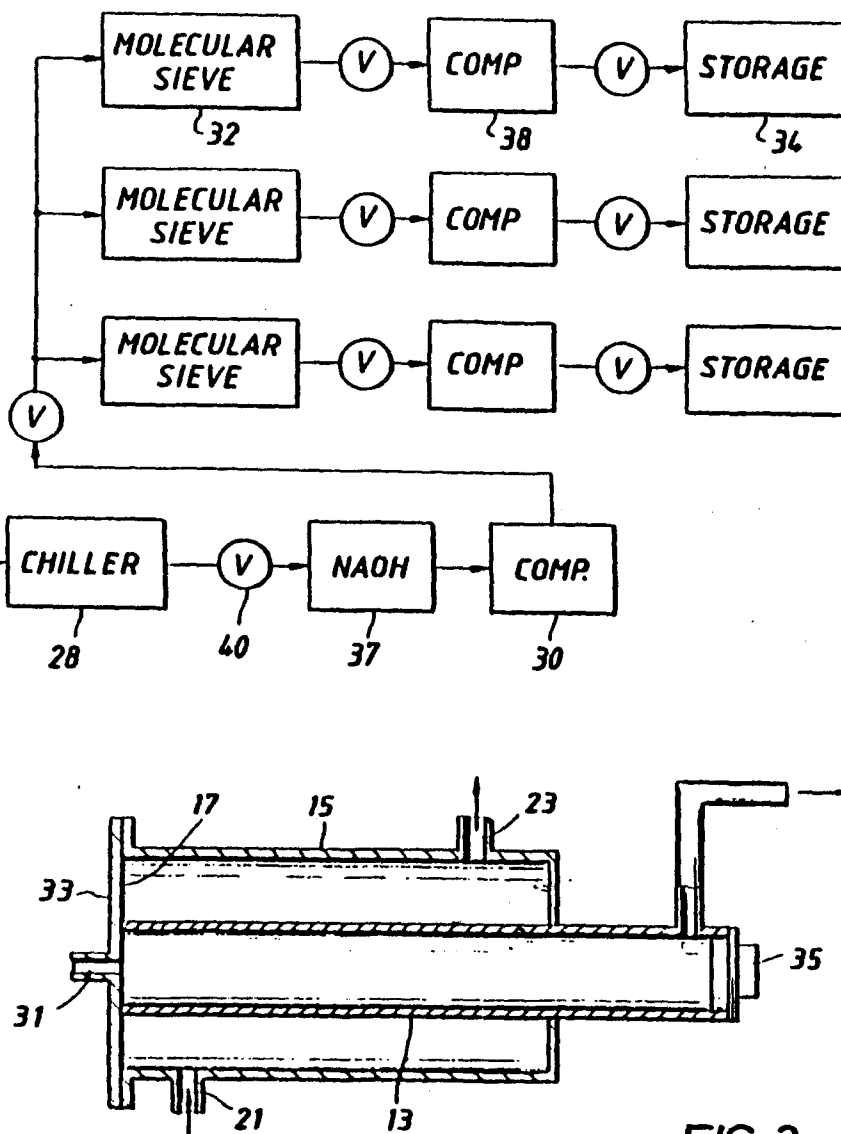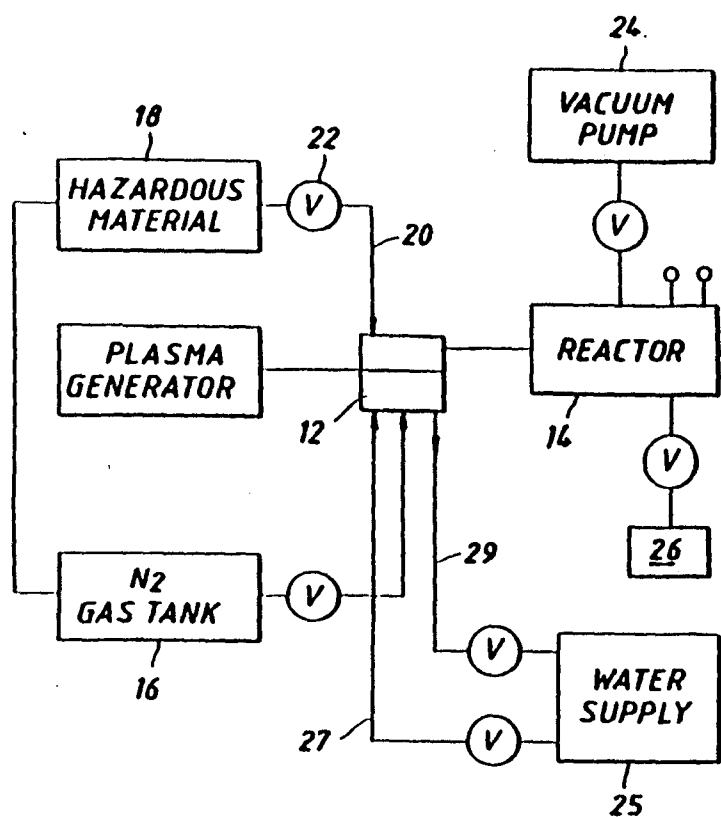
8 Claims, 2 Drawing Sheets

FIG.1

MOLECULAR SIEVE 32 — V → COMP 38 — V → STORAGE 34

MOLECULAR SIEVE — V → COMP — V → STORAGE

MOLECULAR SIEVE — V → COMP — V → STORAGE

VACUUM PUMP 24

HAZARDOUS MATERIAL 18 — V 22

20

PLASMA GENERATOR

12

N2 GAS TANK 16 — V

29

27

REACTOR 16 — V

26

V

V

10

WATER SUPPLY 25

CHILLER 28 — V — NAOH 37 — COMP. 30
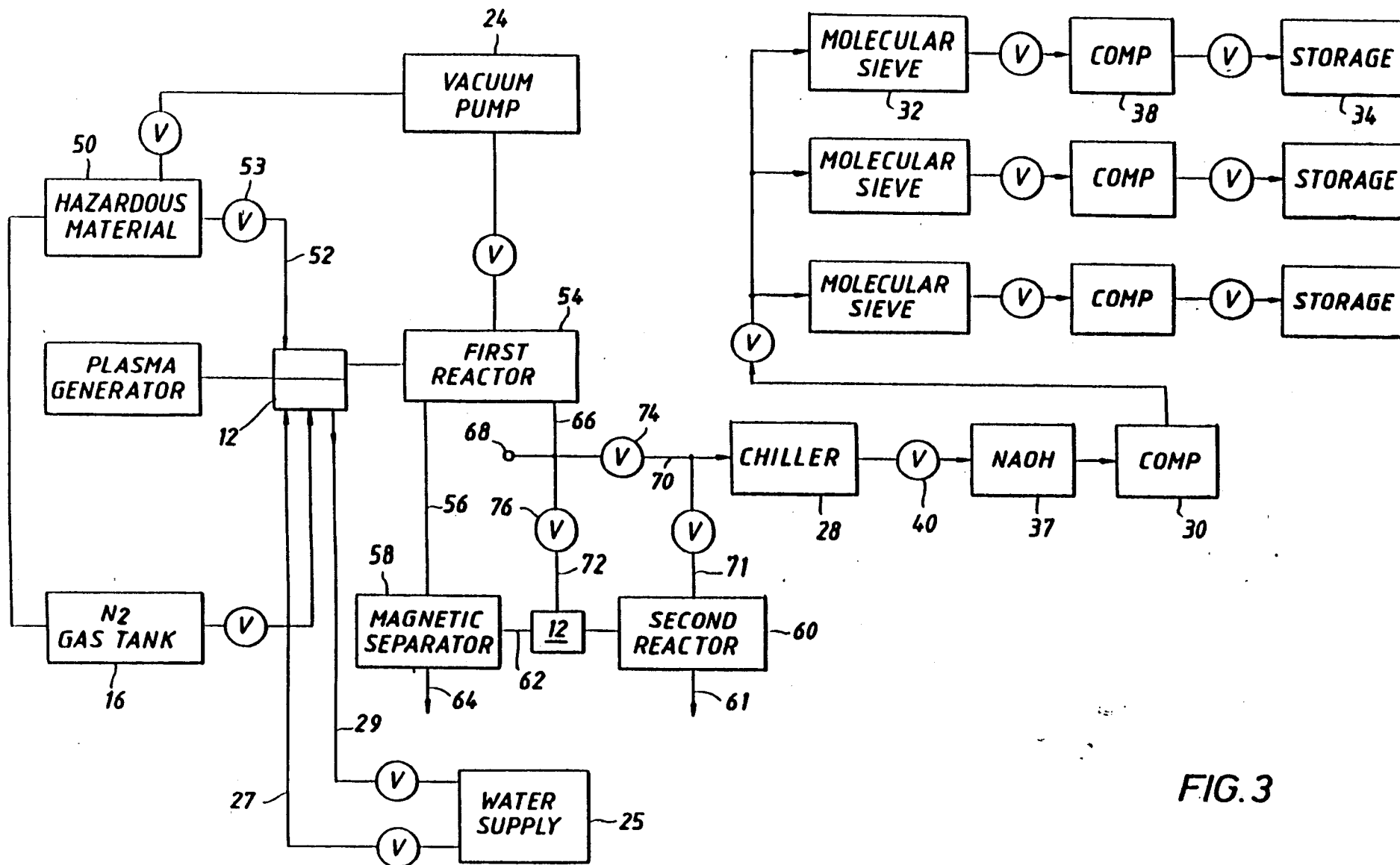
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FIG.2

17   15   23

33

31

35

21   13

FIG.3

METHOD AND APPARATUS FOR TREATMENT OF HAZARDOUS WASTE IN ABSENCE OF OXYGEN

RELATED APPLICATIONS

This application is a continuation-in-part application of U.S. patent application Ser. No. 07/244,318 filed Sept. 15, 1988, now U.S. Pat. No. 4,896,614 issued on Jan. 30, 1990.

BACKGROUND OF THE DISCLOSURE

This invention relates to the destruction of hazardous waste materials, particularly, to a method and apparatus for conversion of hazardous waste material into useful by-products.

The safe disposal of hazardous waste materials is a high priority for both private industry and governmental agencies. A superfund has been established by the government to clean up areas of hazardous waste which present eminent danger to the public health and welfare. Thousands of regulations have been promulgated by the government to insure the safe use and disposal of hazardous materials. Use of some hazardous materials has been banned or extremely restricted. Due to the severity of the problem, various methods have been utilized for disposing of hazardous materials. Research continues in an effort to develop a method for the destruction of hazardous material which is also environmentally safe.

Various methods have been attempted for the disposal of hazardous material, including the use of electric plasma arcs to destroy toxic waste. Plasma generators are known in the prior art. A plasma arc generated by a plasma gun develops an extremely hot temperature zone having temperatures in the range of 10,000° F. to 30,000° F., or above. At such high temperatures, almost all organic and inorganic compounds may be converted into useful by-products.

U.S. Pat. No. 4,644,877 discloses a method and apparatus for the pyroelectric destruction of toxic or hazardous waste materials. The waste materials are fed into a plasma arc burner where they are atomized and ionized, and then discharged into a reaction chamber to be cooled and recombined into product gas and particulate matter. The recombined products are quenched using a spray ring attached to the reaction vessel. An alkaline atomized spray produced by the spray ring neutralizes the recombined products and wets the particulate matter. The product gases are then extracted from the recombining of products using a scrubber, and the product gases are then burned or used for fuel.

U.S. Pat. No. 4,479,443 discloses a method and apparatus for thermal decomposition of stable compounds. High temperatures necessary for decomposition are generated by a plasma generator. U.S. Pat. Nos. 4,438,706 and 4,509,434 disclose a procedure and equipment for destroying waste material. The material is decomposed in a plasma state in the presence of an oxidizing agent so that the waste material is converted into stable combustion products.

U.S. Pat. No. 4,615,285 discloses a method of destroying hazardous waste by means of under-stoichiometric incineration at a temperature of at least 1,200° C. The ratio between injected waste material and oxidant is regulated to give a quotient $CO_2/(CO \times CO_2)$ of less than 0.1.

U.S. Pat. Nos. 4,602,991 and 4,729,891, by the Applicant herein disclose a coal liquefaction process and hydrogen generating method, respectively, wherein the feed stock is heated in an inductive furnace under vacuum conditions.

As is noted above, various methods have been tried for disposing of hazardous waste material. Until the present invention, however, a commercially viable process which combines vacuum, induction and plasma technology for conversion of hazardous materials into useful by-products has not been available.

SUMMARY OF THE INVENTION

The present invention is directed to a method of destroying hazardous waste material, both liquid and solid waste material. The method comprises the steps of converting the hazardous material by exposing it to at least one high temperature plasma arc in the absence of oxygen. The converted gases and any non-gaseous constituents are collected in a depressurized reactor chamber which is devoid of oxygen. Solid waste material is directed through two reaction chambers. The collected gases are then directed through a series of chillers, compressors and molecular sieves for separation of the gases into individual components. The separated components are collected in storage vessels. None of the by-products of the process of the invention are released into the atmosphere.

DETAILED DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features, advantages and objects of the present invention are attained and can be understood in detail, more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

FIG. 1 is a schematic flow diagram of a method of treating hazardous waste material in the absence of oxygen;

FIG. 2 is a partial sectional view of the plasma generator of the invention; and

FIG. 3 is a schematic flow diagram of a method of treating solid hazardous waste material in the absence of oxygen.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1, the system of the invention for treatment of hazardous waste material is generally identified by the reference numeral 10. The system 10 includes a plasma generator 11 and plasma gun 12 connected to a reactor chamber 14. The plasma gun 12 is of a type commercially available. The plasma gun 12 is connected to a power supply which delivers power to operate the plasma gun 12. The plasma arc generated by the plasma gun 12 is sustained by nitrogen or argon gas which is supplied to the plasma gun 12 from a gas supply 16. Hydrogen may also be supplied to aid the conversion of waste material containing oxygen. The hydrogen will combine with the oxygen to form water. The plasma arc generated by the plasma gun 12 is a high temperature plasma sustaining plasma temperatures in

the range of 10,000° F. to 30,000° F., or higher. At such high temperatures, almost all organic and inorganic compounds are split into individual components. While in the preferred embodiment, a plasma gun 12 generates the required temperatures for converting the waste material, it is understood that sufficiently high temperatures for accomplishing the conversion may be developed by other means, such as lasers or induction heating. The conversion of hazardous material may be accomplished at a temperature of 1,200° F. or above.

A source or feedstock of hazardous material 18 is connected to the plasma gun 12 via a feed line 20. The hazardous material is transported to the plasma gun 12 in a flowing slurry of liquid material through the feed line 20. Alternatively, a screw conveyer may be used to transport solid material to the inlet of the plasma gun 12. In the preferred embodiment, the hazardous material is fed to the plasma gun 12 through the feed line 20 at a predetermined rate of approximately three to six gallons per minute. If desired, the hazardous material may be fed to the plasma gun 12 at higher rates. For example, solid waste may be fed at a rate of up to two tons per hour or more. A valve 22 connects the feed line 20 to the hazardous material 18. The valve 22 may be opened or closed to increase or decrease the flow rate of hazardous material transported through the feed line 20.

A partial sectional view of the plasma gun 12 is shown in FIG. 2. Due to the extremely high temperatures generated by the plasma gun 12, a water bath is used to cool the plasma gun 12. The barrel of the plasma gun 12 comprises an inner tube 13 concentrically positioned within an outer tube 15. The inner tube 13 is approximately seven feet eight inches in length and projects outwardly from the end of the outer tube 15 which is approximately six feet in length. Flange support members 17 are mounted about the inner tube 13 and secured to the ends of the outer tube 15. The support members 17 position the inner tube 13 concentrically within the outer tube 15 and close off the annular space 19 defined therebetween. Water is circulated in the annular space 19 for forming a cooling bath about the inner tube 13. Water is directed into the annular space 19 through a water inlet 21 and exits through a water outlet 23. Water is pumped to the plasma gun 12 from a water source 25 through a water line 27 and returned to the water source 25 through a return line 29 so that continuous water circulation is provided to maintain the plasma gun 12 at a relatively cool temperature.

The forward end of the inner tube 13 is provided with an opening 31. The plasma generator control head 33 is connected to the forward end of the inner tube 13. The electrodes of the plasma generator extend through the opening 31 so that the plasma arc is generated within the inner tube 13. The rear end of the inner tube 13 is closed by a removable plug 35. The plug 35 may be removed permitting inspection of the inner tube 13 for pitting or damage from heat or chemical reaction.

The hazardous waste material is incinerated within the inner tube 13. The waste material is delivered to the inner tube 13 via the line 20 which is connected to the plasma generator control head. The plasma gun 12 is connected to the reactor chamber 14 in a suitable manner. The reactor chamber 14 is maintained under vacuum conditions in the range of 10^{-1} to 10^{-3} torr or any lower attainable vacuum, thereby substantially removing all air from the reactor chamber 14. The reactor chamber 14 is evacuated by vacuum pumps 24 connected thereto. A sample container 26 is connected to the reactor chamber 14 for collecting a sample of the gases collected in the reactor chamber 14. The sample of gases is analyzed to insure that the hazardous material has been completely converted to harmless by-products.

From the reactor chamber 14, the collected gases are directed through a chiller 28 for rapidly cooling the gases and then through a NaOH solution tower 37 for converting any hydrochloric acid gases into sodium chloride (NaCl). A compressor 30 is connected to the outlet end of the NaOH tower 37 for pressurizing and directing the collected gases through a series of molecular sieves to remove undesirable impurities in the constituents forming the gas flow from the reactor chamber 14. The gas flow is separated into its individual constituents which are stored in storage vessels 34. Compressors 38 are connected between the molecular sieves 32 and storage vessels 34 for pressurizing the constituents of the gas flow into the storage vessels 34.

As an example, but in no way limiting the scope of the present disclosure, the individual constituents or by-products of the conversion of hazardous materials include nitrogen, hydrogen, carbon dioxide, methane and any silicate, metallic or any other solid constituents that are not converted into a gaseous by-products. The gaseous constituents are separated by passing the gases through the molecular sieves 32 and collecting the individual constituents in the storage vessels 34. The non-gaseous constituents are collected in the reactor 14 and removed upon completion of the conversion process. The reactor 14 includes an internal screw conveyor or the like for expelling any non-gaseous constituents collected in the reactor 14. The hazardous material is thereby converted into harmless by-products which are captured in the storage vessels 34. The process of the present invention is totally environmentally safe as no emissions are released into the atmosphere.

Referring again to FIG. 1, in operation the system 10 is initially pressurized and visually inspected for leaks and pressure drops. Pressures of 50 psi to 80 psi are maintained for a period of time to insure that the system does not leak. After checking that the vacuum pumps 24 are operating properly, the vacuum valves are opened and a vacuum is pulled throughout the system and isolated between closed valves 22 and 40 insuring that all oxygen in the system between the closed valves 22 and 40 is removed. Upon obtaining a vacuum of a minimum of 10^{-1} torr, the plasma gun 12 is activated. The valve 22 is then opened permitting the hazardous material to be delivered to the plasma gun 12. Initially, the pressure in the hazardous material tank is approximately 50 psi. When the pressure has dropped to 5 psi or less, the hazardous material tank 18 is empty and the valve 22 is shut off. The hazardous material is converted in the plasma arc formed by the plasma generator within the inner tube 13 of the plasma gun 12. The converted gases are collected in the reactor chamber 14. During the conversion of the hazardous material, the pressure in the system 10 increases. The valve 40 however is maintained in the closed position until the system pressure reaches the level of approximately 15 psi. Prior to opening the valve 40, a sample of the converted gases is collected in the sample container 26. The sample container 26 is double valved to separate it from the system 10. The sample of gases is then analyzed to determine whether the hazardous materials have been destroyed. If any traces of hazardous material remains in the sam-

ple, the gases are collected and passed through the plasma generator a second time.

Referring now to FIG. 3, a configuration of the system 10 is shown for treatment of solid hazardous material. The system is substantially the same as shown in FIG. 1 and therefore like reference numerals have been used to identify like components. As shown in FIG. 3, the solid waste material is collected in a collection vessel 50. The solid waste material, for example, tires or the like, is fed to the plasma guns 12 through a feedline or conduit 52 at a predetermined rate of up to two tons per hour or more upon opening a valve 53. A screw conveyor or the like transports the solid hazardous waste material from the collection vessel 50 to the plasma guns 12 via the conduit 52. The plasma guns 12 may be connected in series or may be spaced around a plenum which, when energized, will form a concentrated hot zone through which the solid waste material will flow and be collected in the reactor 54. As was discussed above in relation to the system shown in FIG. 1, a vacuum is pulled by the vacuum pumps 24 insuring that all oxygen in the system shown in FIG. 3 is removed. Once the proper vacuum is achieved, the plasma guns 12 are activated and solid waste material is flowed through the hot zone created by the plasma guns.

As the solid waste material passes through the hot zone, it is converted into non-hazardous components and collected in the reactor 54. At this stage of the process, the collection vessel 54 includes carbon black and disassociated gaseous components of the solid waste material in a non-hazardous states. Also, depending on the composition of the solid waste material passed through the hot zone created by the plasma guns 12, some solids such as metals, cans, or the like may be collected in the reactor 54. While the plasma guns 12 create an extremely hot zone, not all components of the solid waste material stream will be converted into a gaseous effluent. Complete conversion of the solid waste material into a gaseous state is dependent upon the volume and flow rate of solid waste material passing through the temperature zone created by the plasma guns 12.

The carbon black and nonconverted solid components of the hazardous material are collected in the bottom of the reactor 14 and transported via a screw conveyor or the like through line 56 to a magnetic separator 58. In the magnetic separator 58 the carbon black is separated from the metal solids and transported to the reactor 60 via a line 62. The solid metal material such as cans, are released from the magnetic separator 50 through a discharge line 64 to a storage vessel for subsequent recycling or other use.

The disassociated non-hazardous gaseous components of the solid waste material are removed from the reactor 54 via a line 66. A volatile organic compound analyzer 68 is incorporated in the line 66 for analyzing the gas stream discharge from the reactor 54. The gas stream may be discharged directly to the chillers 28 via the line 70 or directed to the reactor 60 via the line 72. Valves 74 and 76 are incorporated in the lines 70 and 72, respectively, for directing the gas stream along the selected path.

Lines 62 and 72 join at the inlet of the vessel 60. The carbon black and gas stream from lines 62 and 72 pass through a second hot zone formed by a plasma gun 12 mounted at the inlet of the reactor 60. The gases and carbon black collected in the reactor 54 are passed through a second high temperature zone to insure that hazardous components in the solid waste material are completely converted into individual non-hazardous by products such as nitrogen, hydrogen, and carbon dioxide which are directed to the chillers 28 via line 71 and subsequently collected in the storage vessels 34 in the manner described above in relation to FIG. 1. The reactor 60 includes an internal screw conveyor or the like for expelling the carbon black collected at the bottom thereof via outlet conduit 61 into storage tanks for subsequent use.

When handling hazardous materials, certain steps must be taken to prevent hazards or mishaps from occurring. In the system 10, all components are fabricated of stainless steel material. The system is completely vacuumed as discussed above and all valves used are vacuum valves. In the event of a malfunction, solenoid valves are connected to an emergency shut off on the plasma generator and are utilized to stop the flow of hazardous material. Two manual valves are also incorporated in the system to shut off the flow of hazardous material in case of electrical failure or the like. Pressure gauges 36 monitor the pressure in the system and high temperature gaskets are used at the connections of various components forming the system. A thermal couple 38 is also incorporated in the system for reading or monitoring temperatures of the gases in the system. All exposed pipe of the system is sprayed with water for maintaining it a relatively low temperature.

While the foregoing is directed to the preferred embodiment of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims which follow.

What is claimed is:

1. A method of converting solid hazardous waste material into useful by-products, comprising the steps of:

(a) introducing the solid waste material into a first high temperature zone generated by at least one plasma gun and converting the waste material into a mixture of carbon black, gases and metallic non-converted material;

(b) collecting said mixture in a first reactor chamber in the absence of oxygen for preventing the recombination of said mixture with oxygen;

(c) discharging the carbon black and metallic nonconverted material into a magnetic separator for separating the metallic material from the carbon black and collecting said metallic material for subsequent use;

(d) directing said carbon black through a second high temperature zone into a second reactor chamber for further separation and conversion of hazardous constituents into non-hazardous gases;

(e) directing the gases from said first and second reactor chambers through cooling apparatus for reducing the temperature of said gases;

(f) passing said gases through molecular sieve apparatus permitting selected constituents of said gases to pass through said molecular sieve apparatus; and

(f) collecting said selected constituents in storage vessels.

2. The method of claim 1 including the step of forming a vacuum of at least 10^{-1} torr for removing substantially all the oxygen from the reactor chambers.

3. The method of claim 2 including the step of collecting and analyzing a sample of the gases exiting said first reactor chamber.

4. The method of claim 3 including the step of circulating water about the plasma gun for maintaining a continuous cooling bath about the plasma gun.

5. The method of claim 1 wherein said carbon black is removed from said second reactor chamber and stored for subsequent use.

6. The method of claim 1 wherein said gases from said first reactor chamber are combined with said carbon

black and directed through said second temperature zone.

7. The method of claim 1 wherein said first temperature zone is created by a plurality of plasma guns connected in series.

8. The method of claim 1 wherein said first temperature zone is created by a plurality of plasma guns spaced about a plenum.

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United States Patent [19]

Kulkarni

[11] Patent Number: 4,896,614

[45] Date of Patent: Jan. 30, 1990

[54] **METHOD AND APPARATUS FOR TREATMENT OF HAZARDOUS WASTE IN ABSENCE OF OXYGEN**

[76] Inventor: Prabhakar Kulkarni, 12027 Circle Dr. E., Houston, Tex. 77071

[21] Appl. No.: 244,318

[22] Filed: Sep. 15, 1988

[51] Int. Cl.⁴ F23G 7/00
[52] U.S. Cl. 110/346; 110/237; 110/238
[58] Field of Search 110/341, 346, 237, 238

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,832,519	8/1974	Wolf et al. .
4,438,706	3/1984	Boday et al. .
4,479,443	10/1984	Faldt et al. .
4,509,434	4/1985	Boday et al. .
4,602,991	7/1986	Kulkarni .
4,615,285	10/1986	Bessell et al. .
4,644,877	2/1987	Barton .
4,688,495	8/1987	Galloway .... 110/237 X
4,699,721	10/1987	Meehan et al. .... 110/237 X
4,729,891	3/1988	Kulkarni .

Primary Examiner—Edward G. Favors
Attorney, Agent, or Firm—Gunn, Lee & Miller

[57] **ABSTRACT**

Hazardous waste treatment method and apparatus are disclosed in the preferred and illustrated emboldiment. A feedstock of hazardous waste material is combusted in a plasma generator in the absence of oxygen and converted into a gaseous outflow which is collected in a reactor chamber. The gaseous outflow is cooled and separated into selected constituents which are collected in storage vessels.
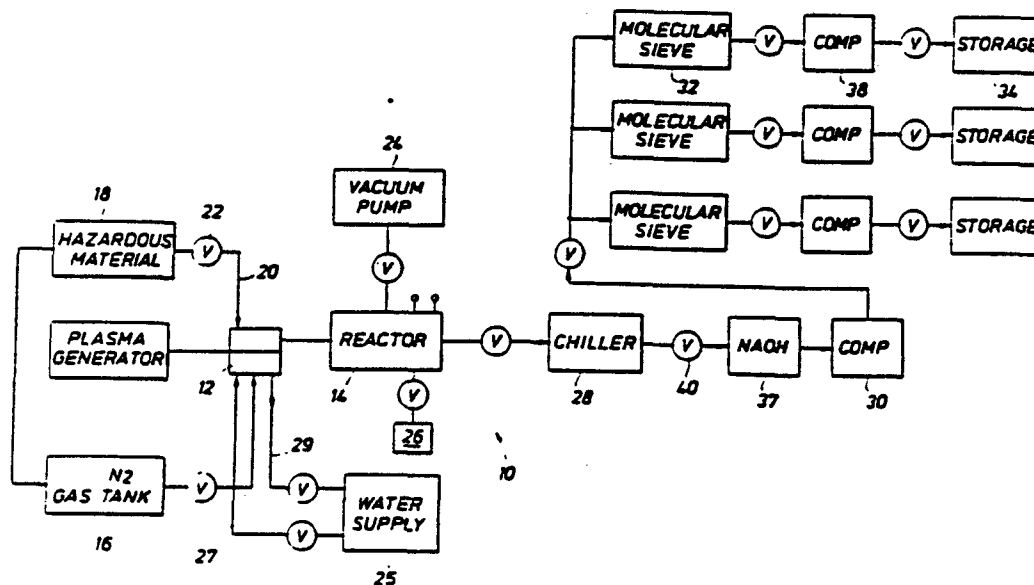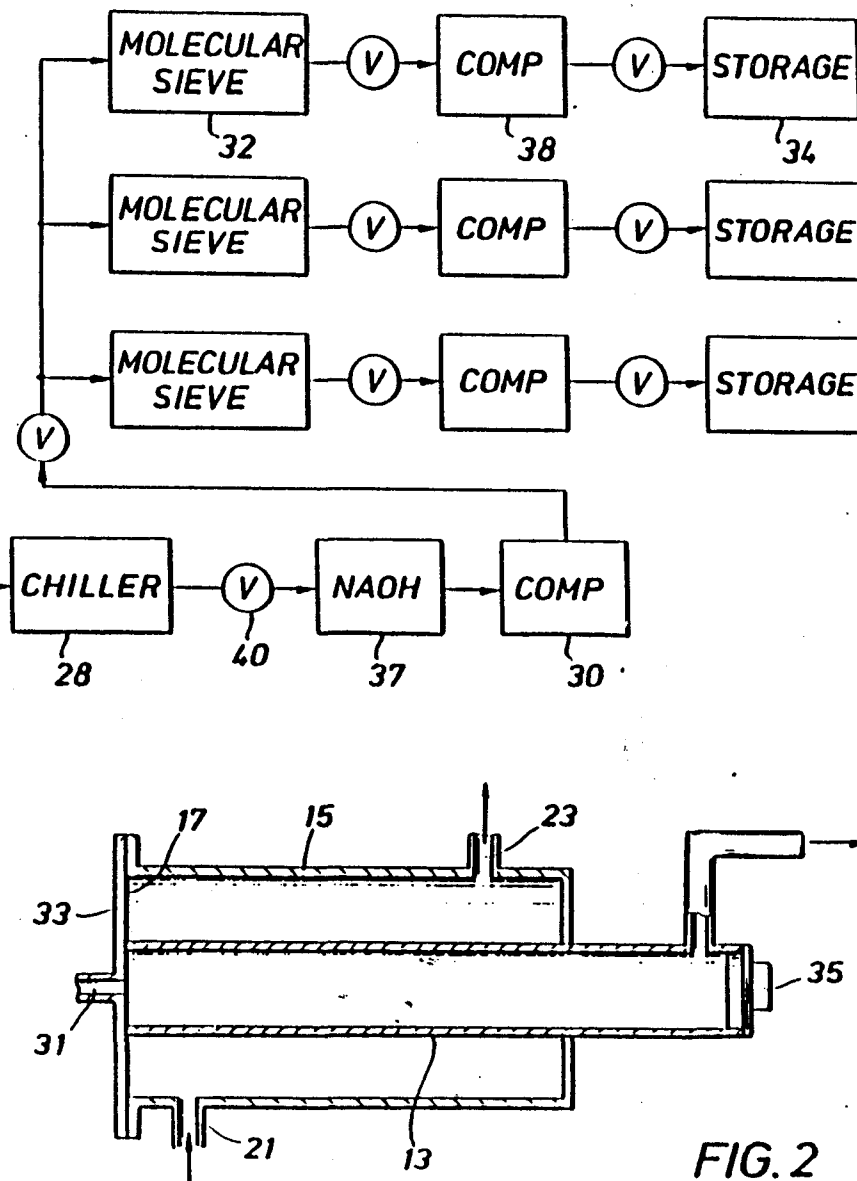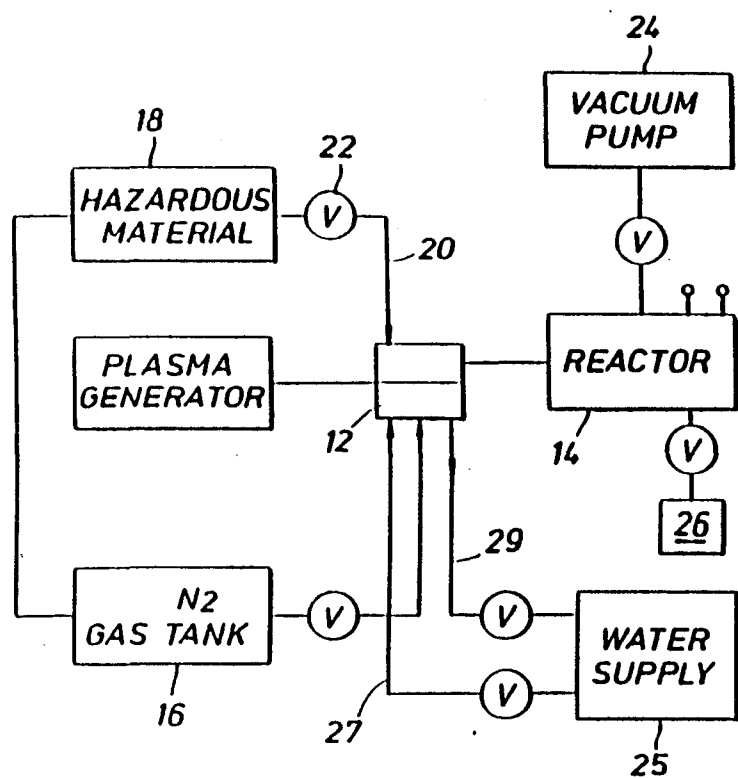
6 Claims, 1 Drawing Sheet

FIG.1

FIG.2

METHOD AND APPARATUS FOR TREATMENT OF HAZARDOUS WASTE IN ABSENCE OF OXYGEN

BACKGROUND OF THE DISCLOSURE

This invention relates to the destruction of hazardous waste materials, particularly, to a method and apparatus for conversion of hazardous waste material into useful by-products.

The safe disposal of hazardous waste materials is a high priority for both private industry and governmental agencies. A superfund has been established by the government to clean up areas of hazardous waste which present eminent danger to the public health and welfare. Thousands of regulations have been promulgated by the government to insure the safe use and disposal of hazardous materials. Use of some hazardous materials has been banned or extremely restricted. Due to the severity of the problem, various methods have been utilized for disposing of hazardous materials. Research continues in an effort to develop a method for the destruction of hazardous material which is also environmentally safe.

Various methods have been attempted for the disposal of hazardous material, including the use of electric plasma arcs to destroy toxic waste. Plasma generators are known in the prior art. A plasma arc generated by a plasma gun develops an extremely hot temperature zone having temperatures in the range of 10,000° F. to 30,000° F., or above. At such high temperatures, almost all organic and inorganic compounds may be converted into useful by-products.

U.S. Pat. No. 4,644,877 discloses a method and apparatus for the pyroelectric destruction of toxic or hazardous waste materials. The waste materials are fed into a plasma arc burner where they are atomized and ionized, and then discharged into a reaction chamber to be cooled and recombined into product gas and particulate matter. The recombined products are quenched using a spray ring attached to the reaction vessel. An alkaline atomized spray produced by the spray ring neutralizes the recombined products and wets the particulate matter. The product gases are then extracted from the recombining of products using a scrubber, and the product gases are then burned or used for fuel.

U.S. Pat. No. 4,479,443 discloses a method and apparatus for thermal decomposition of stable compounds. High temperatures necessary for decomposition are generated by a plasma generator. U.S. Pat. Nos. 4,438,706 and 4,509,434 disclose a procedure and equipment for destroying waste material. The material is decomposed in a plasma state in the presence of an oxidizing agent so that the waste material is converted into stable combustion products.

U.S. Pat. No. 4,615,285 discloses a method of destroying hazardous waste by means of under-stoichiometric incineration at a temperature of at least 1,200° C. The ratio between injected waste material and oxidant is regulated to give a quotient $CO_2/(CO+CO_2)$ of less than 0.1.

U.S. Pat. Nos. 4,602,991 and 4,729,891, by the Applicant herein disclose a coal liquefaction process and hydrogen generating method, respectively, wherein the feed stock is heated in an inductive furnace under vacuum conditions.

As is noted above, various methods have been tried for disposing of hazardous waste material. Until the present invention, however, a commercially viable process which combines vacuum, induction and plasma technology for conversion of hazardous materials into useful by-products has not been available.

SUMMARY OF THE INVENTION

The present invention is directed to a method of destroying hazardous waste material. The method comprises the steps of converting the hazardous material by exposing it to a high temperature plasma arc in the absence of oxygen. The converted gases and any non-gaseous constituents are collected in as depressurized reactor chamber which is devoid of oxygen. The collected gases are then directed through a series of chillers, compressors and molecular sieves for separation of the gases into individual components. The separated components are collected in storage vessels. None of the by-products of the process of the invention are released into the atmosphere.

DETAILED DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features, advantages and objects of the present invention are attained and can be understood in detail, more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

FIG. 1 is a schematic flow diagram of a method of treating hazardous waste material in the absence of oxygen; and

FIG. 2 is a partial sectional view of the plasma generator of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1, the system of the invention for treatment of hazardous waste material is generally identified by the reference numeral 10. The system 10 includes a plasma generator 11 and plasma gun 12 connected to a reactor chamber 14. The plasma gun 12 is of a type commercially available. The plasma gun 12 is connected to a power supply which delivers power to operate the plasma gun 12. The plasma arc generated by the plasma gun 12 is sustained by nitrogen or argone gas which is supplied to the plasma gun 12 from a gas supply 16. Hydrogen may also be supplied to aid the conversion of waste material containing oxygen. The hydrogen will combine with the oxygen to form water. The plasma arc generated by the plasma gun 12 is a high temperature plasma sustaining plasma temperatures in the range of 10,000° F. to 30,000° F., or higher. At such high temperatures, almost all organic and inorganic compounds are split into individual components. While in the preferred embodiment, a plasma gun 12 generates the required temperatures for converting the waste material, it is understood that sufficiently high temperatures for accomplishing the conversion may be developed by other means, such as lasers or induction heating. The conversion of hazardous material may be accomplished at a temperature of 1,200° F. or above.

A source or feedstock of hazardous material 18 is connected to the plasma gun 12 via a feed line 20. The hazardous material is transported to the plasma gun 12 in a flowing slurry of liquid material through the feed line 20. Alternatively, a screw conveyer may be used to transport solid material to the inlet of the plasma gun 12. In the preferred embodiment, the hazardous material is fed to the plasma gun 12 through the feed line 20 at a predetermined rate of approximately three to six gallons per minute. If desired, the hazardous material may be fed to the plasma gun 12 at higher rates. For example, solid waste may be fed at a rate of up to two tons per hour or more. A valve 22 connects the feed line 20 to the hazardous material 18. The valve 22 may be opened or closed to increase or decrease the flow rate of hazardous material transported through the feed line 20.

A partial sectional view of the plasma gun 12 is shown in FIG. 2. Due to the extremely high temperatures generated by the plasma gun 12, a water bath is used to cool the plasma gun 12. The barrel of the plasma gun 12 comprises an inner tube 13 concentrically positioned within an outer tube 15. The inner tube 13 is approximately seven feet eight inches in length and projects outwardly from the end of the outer tube 15 which is approximately six feet in length. Flange support members 17 are mounted about the inner tube 13 and secured to the ends of the outer tube 15. The support members 17 position the inner tube 13 concentrically within the outer tube 15 and close off the annular space 19 defined therebetween. Water is circulated in the annular space 19 for forming a cooling bath about the inner tube 13. Water is directed into the annular space 19 though a water inlet 21 and exits through a water outlet 23. Water is pumped to the plasma gun 12 from a water source 25 though a water line 27 and returned to the water source 25 through a return line 29 so that continuous water circulation is provided to maintain the plasma gun 12 at a relatively cool temperature.

The forward end of the inner tube 13 is provided with an opening 31. The plasma generator control head 33 is connected to the forward end of the inner tube 13. The electrodes of the plasma generator extend through the opening 31 so that the plasma arc is generated within the inner tube 13. The rear end of the inner tube 13 is closed by a removable plug 35. The plug 35 may be removed permitting inspection of the inner tube 13 for pitting or damage from heat or chemical reaction.

The hazardous waste material is incinerated within the inner tube 13. The waste material is delivered to the inner tube 13 via the line 20 which is connected to the plasma generator control head. The plasma gun 12 is connected to the reactor chamber 14 in a suitable manner. The reactor chamber 14 is maintained under vacuum conditions in the range of 10^{-1} to 10^{-3} torr or any lower attainable vacuum, thereby substantially removing all air from the reactor chamber 14. The reactor chamber 14 is evacuated by vacuum pumps 24 connected thereto. A sample container 26 is connected to the reactor chamber 14 for collecting a sample of the gases collected in the reactor chamber 14. The sample of gases is analyzed to insure that the hazardous material has been completely converted to harmless by-products.

From the reactor chamber 14, the collected gases are directed through a chiller 28 for rapidly cooling the gases and then through a NaOH solution tower 37 for converting any hydrochloric acid gases into sodium chloride (NaCl). A compressor 30 is connected to the outlet end of the NaOH tower 37 for pressurizing and directing the collected gases through a series of molecular sieves to remove undesirable impurities in the constituents forming the gas flow from the reactor chamber 14. The gas flow is separated into its individual constituents which are stored in storage vessels 34. Compressors 38 are connected between the molecular sieves 32 and storage vessels 34 for pressurizing the constituents of the gas flow into the storage vessels 34.

As an example, but in no way limiting the scope of the present disclosure, the individual constituents or by-products of the conversion of hazardous material may include nitrogen, hydrogen, carbon dioxide, methane and any silicate, metallic or any other solid constituents that are not converted into a gaseous by-product. The gaseous constituents are separated by passing the gases through the molecular sieves 32 and collecting the individual constituents in the storage vessels 34. The non-gaseous constituents are collected in the reactor 14 and removed upon completion of the conversion process. The reactor 14 includes an internal screw conveyor or the like for expelling any non-gaseous constituents collected in the reactor 14. The hazardous material is thereby converted into harmless by-products which are captured in the storage vessels 34. The process of the present invention is totally environmentally safe as no emissions are released into the atmosphere.

Referring again to FIG. 1, in operation the system 10 is initially pressurized and visually inspected for leaks and pressure drops. Pressures of 50 psi to 80 psi are maintained for a period of time to insure that the system does not leak. After checking that the vacuum pumps 24 are operating properly, the vacuum valves are opened and a vacuum is pulled throughout the system and isolated between closed valves 22 and 40 insuring that all oxygen in the system between the closed valves 22 and 40 is removed. Upon obtaining a vacuum of a minimum of 10^{-1} torr, the plasma gun 12 is activated. The valve 22 is then opened permitting the hazardous material to be delivered to the plasma gun 12. Initially, the pressure in the hazardous material tank is approximately 50 psi. When the pressure has dropped to 5 psi or less, the hazardous material tank 18 is empty and the valve 22 is shut off. The hazardous material is converted in the plasma arc formed by the plasma generator within the inner tube 13 of the plasma gun 12. The converted gases are collected in the reactor chamber 14. During the conversion of the hazardous material, the pressure in the system 10 increases. The valve 40 however is maintained in the closed position until the system pressure reaches the level of approximately 15 psi. Prior to opening the valve 40, a sample of the converted gases is collected in the sample container 26. The sample container 26 is double valved to separate it from the system 10. The sample of gases is then analyzed to determine whether the hazardous materials have been destroyed. If any traces of hazardous material remains in the sample, the gases are collected and passed through the plasma generator a second time.

When handling hazardous materials, certain steps must be taken to prevent hazards or mishaps from occurring. In the system 10, all components are fabricated of stainless steel material. The system completely vacuumed as discussed above and all valves used are vacuum valves. In the event of a malfunction, solenoid valves are connected to an emergency shut off on the plasma generator and are utilized to stop the flow of hazardous material. Two manual valves are also incorporated in

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the system to shut off the flow of hazardous material in case of electrical failure or the like. Pressure gauges 36 monitor the pressure in the system and high temperature gaskets are used at the connections of various components forming the system. A thermal couple 38 is also incorporated in the system for reading or monitoring temperatures of the gases in the system. All exposed pipe of the system is sprayed with water for maintaining it a relatively low temperature.

While the foregoing is directed to the preferred embodiment of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims which follow.

What is claimed is:

1. A method of converting hazardous waste material into useful by-products, comprising the steps of:

   (a) introducing the waste material into a plasma arc generated by a plasma gun and converting the waste material into a gaseous outflow;

   (b) collecting said gaseous outflow in a reactor chamber in the absence of oxygen for preventing the recombination of said gaseous outflow with oxygen;

   (c) directing said gaseous outflow through cooling apparatus for reducing the temperature of said gaseous outflow;

   (d) passing said gaseous outflow through molecular sieve apparatus permitting selected constituents of said gaseous outflow to pass through said molecular sieve apparatus; and

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   (e) collecting said selected constituents in storage vessels.

2. The method of claim 1 including the step of forming a vacuum of at least 10^{-1} torr for removing substantially all the oxygen from the reactor chamber.

3. The method of claim 2 including the step of collecting and analyzing a sample of the gaseous outflow.

4. The method of claim 3 including the step of circulating water about the plasma gun for maintaining a continuous cooling bath about the plasma gun.

5. The method of claim 4 including the step of monitoring temperature and pressure of the gaseous outflow.

6. A method of converting hazardous waste material into useful by-products, comprising the steps of:

   (a) introducing the waste material into a high temperature zone of at least 1,200° F. and converting the waste material into a gaseous outflow;

   (b) collecting said gaseous outflow in a reactor chamber in the absence of oxygen for preventing the recombination of said gaseous outflow with oxygen;

   (c) directing said gaseous outflow through cooling apparatus for reducing the temperature of said gaseous outflow;

   (d) passing said gaseous outflow through molecular sieve apparatus permitting selected constituents of said gaseous outflow to pass through said molecular sieve apparatus; and

   (e) collecting said selected constituents in storage vessels.

* * * * *

Testing

TNRCC and EPA tests and permits

Barry R. McBee, *Chairman*

R. B. "Ralph" Marquez, *Commissioner*

John M. Baker, *Commissioner*

\n Pearson, *Executive Director*

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

Protecting Texas by Reducing and Preventing Pollution

September 29, 1995

Mr. Kenneth L. Petersen, Jr.
Small, Craig and Werkenthin, P.C.
100 Congress Ave., Suite 100
Austin, Texas 78711-4099

Re: Quantum Tech, Inc.(QTI)
     Industrial Solid Registration No. 38577

Dear Mr. Petersen:

We have reviewed your letters dated August 11, 1995 and August 14, 1995, and a QTI submittal dated April, 26, 1995. In your letters, you request that QTI obtain a regulatory acknowledgment that, within specified parameters, the QTI plasma arc technology may be marketed on a case-by-case basis, without the necessity of formal permitting under the Texas Solid Waste Disposal Act. In your letter, you have also provided an initial, general specification, both for the raw materials and the product (commercial grade AA methanol) to be produced. In response to your letter, we have provided the notification requirements for off-site and on-site facilities, and we have provided comments on the general specifications you have proposed. In addition, we have included information on current regulatory initiatives in relation to processes such as QTI. In general, we acknowledge that the QTI plasma arc process may be a legitimate recycling technology based upon site specific conditions discussed herein.

Notification Requirements

We have stated in our letter dated August 29, 1994, "The only applications where the Agency may believe that a recycling exemption may be appropriate are where the wastes (secondary materials) processed and the off gases produced must meet constant specifications." In essence, QTI, or the appropriate generator should provide the specifications for the secondary materials and/or wastes to be used to produce AA grade methanol. Below, we will set out the notification requirements for off-site and on-site facilities that desire to use the QTI process.

Off-site Facilities

In certain instances the QTI process may be exempt from permitting when used in an off-site application for the production of commercial specification AA grade methanol. The off-site facility must be able to document that the facility:

- Accepts and recycles only non-hazardous waste and fulfills all 30 TAC 335.6 and 30 TAC 335.24 requirements; or
- Only accepts materials that meet the required incoming specification, and so may be considered to be legitimate substitutes for on-specification raw materials, and therefore, not wastes; and
- Immediately feeds hazardous wastes (i.e., materials not meeting raw material specifications) to the unit, without prior storage and/or processing, and fulfills all Title 30 Texas Administrative Code (TAC) 335.6 and 30 TAC 335.24 requirements; or
- Accepts, stores and processes wastes, pursuant to a hazardous waste permit, prior to recycling.

In each case involving wastes set out above, once the wastes meet established site specific specifications, the wastes become raw materials. These raw materials are not subject to Federal or State waste management requirements, so long as the materials are used to produce commercial specification AA methanol.

A facility hazardous waste permit may also contain provisions regulating any non-hazardous industrial solid wastes accepted and/or processed pursuant to 30 TAC 335.24(I). In addition, QTI would also be required to maintain extensive records regarding products pursuant to Title 40 Code of Federal Regulations (CFR) 261.2(f).

Pursuant to 30 TAC 335.6(a), QTI is required to notify the Texas Natural Resource Conservation Commission (TNRCC) of industrial lid waste activities at least 90 days prior to commencing rage or processing. This notification must contain all pertinent information to allow the TNRCC to verify that the

facility meets all applicable regulations. QTI should provide, in the site-specific notification, the incoming specifications for the wastes to be accepted at the facility, and the statement that commercial grade AA methanol will be manufactured. QTI should include in each notification a waste analysis plan specific to that site that will ensure that the incoming wastes accepted do indeed match the desired incoming specifications. The waste analysis plan should specify who will perform the testing, and on a site specific basis, should list out the specific constituents to be analyzed for and the methods to be used. QTI must also state, in each notification, whether off-specification methanol will be reprocessed, and in what manner.

In addition, the QTI must, prior to construction of the equipment needed to conduct the process, obtain all appropriate air approvals, such as a standard exemption or a permit. Individual constituent feedrates, such as for metals, may be established in air authorizations. Wastewater effluent standards may likewise be established.

On-site Facilities

In certain instances, the QTI process may be exempt from permitting when used in an on-site waste management application at an industrial facility for the production of commercial specification AA grade methanol. The on-site facility must be able to document that the facility:

- Only processes materials that meet the required specification, and so may be considered to be legitimate substitutes for on-specification raw materials, and therefore, not wastes; and;
- Feeds hazardous wastes (i.e., materials not meeting raw material specifications) to the unit, without prior storage and/or processing, and fulfills all 30 TAC 335.6 and 30 TAC 335.24 requirements; or
- Stores or processes hazardous waste materials in authorized units, such as less-than-90-day tanks or permitted tanks, and fulfills all 30 TAC 335.6 and 30 TAC 335.24 requirements; or

- Accepts and recycles only non-hazardous waste and fulfills all 30 TAC 335.6 and 30 TAC 335.24 requirements.

Pursuant to 30 TAC 335.6(a), the generator installing the QTI process is required to notify the TNRCC of industrial solid waste activities at least 90 days prior to commencing storage and processing of industrial solid wastes. This notification must contain all pertinent information to allow the TNRCC to verify that the facility meets all applicable regulations. The generator should provide, in the site-specific notification, the specifications for the incoming materials to be stored or processed at the facility, and a statement that commercial grade AA methanol will be manufactured. The generator must also state, in each notification, whether off-specification methanol will be reprocessed, and in what manner.

The generator should include in each notification a materials analysis plan specific to that site. In addition, the generator may be required to maintain records required pursuant to 40 CFR 261.2(f).

In addition, the generator must, prior to construction of the equipment needed to conduct the process, obtain all appropriate air approvals, such as a standard exemption or a permit. Individual constituent feedrates, such as for metals, may be established in air authorizations

General Material Specifications

In your letter, you have stated that incoming materials meeting the following criteria can be used in the QTI system as raw materials for the production of AA grade methanol:

- Total Halogens - 5%;
- Total Chlorine - 1%;
- Total Metallics - 5%;
- Total Mercury - 1%;
- Total Arsenic - 1%;
  Minimum Carbon - 45%; and
- No physical processing of the material will be required prior to introduction to the Plasma Arc Process.

Regarding these proposed specifications, the TNRCC Industrial and Hazardous Waste (I&HW) Division believes that the halogen and carbon specifications, as proposed, are generally sufficient to ensure that legitimate recycling activities are proposed, provided that the resulting material is used as specified for the production of AA grade methanol and not in a manner constituting disposal. Please be aware that while we generally agree that the carbon and hydrogen specifications seem adequate, we would still need appropriate notification of a facility specific secondary material specification. Any approvals would be on a site-by-site basis. However, we are concerned about the metal specifications, in particular the mercury limit. We note that in numerous telephone conversations in August and September, Mr. Prabhakar Kulkarni of QTI has stated that he would accept a 0.5% by weight mercury limit. We note that a separate ash or non-volatile constituent limit may also be appropriate. Constituent levels found in coal may provide a baseline. We have attached constituent data for coal to this letter.

Regulatory Initiatives

We would also like to inform you of some other initiatives that the TNRCC is pursuing. Through these initiatives, we are hoping to bring a more common sense approach to the way recycling rules are interpreted.

As we have told you in previous correspondence, we feel that in instances where QTI produces a commercially acceptable specification product from incoming materials meeting established specifications, the QTI process appears to be a recycling process, and that the products are not considered to be hazardous wastes unless burned as fuels. In fact, when the process produces a specification synthesis gas (syngas) from specification raw materials, we feel that the process resembles a manufacturing process. In essence, we feel that there is no technical difference between methanol produced from the QTI process and methanol produced from other typical manufacturing cesses using syngas, so long as the methanol meets the same specification and the QTI methanol contains no "toxics along for the ride." As a result of our view, we are working to change

EPA's interpretation of 40 CFR 261.2(e)(1)(I) regarding materials burned for energy recovery. We have attached a memo addressing this issue to this letter, which outlines our position on this issue. We will notify you if EPA modifies its position.

In addition, the TNRCC, as a participant in the Western Governor's Association Interstate Technology and Regulatory Cooperation Workgroup, is examining the uses and regulation of various plasma arc technologies for waste treatment. This effort is envisioned to be a cooperative effort between the regulated community, the State regulators, and the Federal regulators. We will make you aware of the next meeting of this group.

Please also be aware of current EPA efforts to amend the current Definition of Solid Waste specifically to address the regulatory status of recycling. It is possible that the results of this EPA effort may affect representations made in this letter.

In conclusion, we would like to reiterate that the TNRCC supports the development of this innovative technology, and is quite enthusiastic about the prospects of real waste minimization that may be realized. If you have questions about this letter, please call William J. Shafford of the Permits Section, Industrial and Hazardous Waste Division at (512) 239-6621.

Sincerely,

Minor Brooks Hibbs, P.E., Director
Industrial and Hazardous Waste Division
Texas Natural Resource Conservation Commission

Attachment

MBH/WJS/bs

⌐⌐: William J. Shafford, TNRCC I&HW, Permits Section - Austin

QUANTUM TECH, L. L. C.

TEST-BURN COMPLIANCE REPORT

TWC PERMIT NO. HW-50259-001

EPA PERMIT NO. TXD982556664-1

Prepared For
Texas Natural Resource Conservation Commission
Austin, Texas

Prepared By
Quantum Tech, L.L.C.
8660 Scranton, # B
Houston, TX 77075

MEMO

TO: Compliance Division, Hazardous Waste Permit Division

FROM: John Survis, Source and Mobile Monitoring Section JES

DATE: April 18, 1994

SUBJECT: Stack Test Report Review

TNRCC PERMIT NO. __HW-50259-001__

COMPANY NAME __Quannum Tech__   ACCOUNT NO. __HG-4351-C__

CITY __Houston__   COUNTY __Harris__   REGION __12__

SOURCE TESTED __Plasma Arc Reactor__

TESTING REQUIRED BY   **PERMIT**   NSPS   PSD   OTHER _____

TEST DATE(S) __12-7, 13, 28-93 and 1-10-94__   DATE REPORT RECEIVED __March 31, 1994__

NAME OF TESTING ORGANIZATION __Anacon__

AVERAGE OPERATING LEVEL OF FACILITY DURING TESTS __0.231 to 0.580 gallons benzene per minute__

NORMAL _____   DESIGN _____   MAXIMUM _____

Test Report is Acceptable _____XX_____ Test Report is Not Acceptable _____
(see results and discussion for compliance status)

Pollutant	Pollutant Conc (ppm)	PMR* (lb/hr)	TACB Reg (Rule No.)	PSD (lb/hr)	Reg (lb/hr)	Permit (lb/hr)	Allowables Exceeded (Yes or No)
N/A							N/A
N/A							N/A

Reported or Reviewer's Results (highlight appropriate response)	Allowables (include units)

DISCUSSION

This testing was conducted to provide documentation that the plasma arc reactor could attain a minimum destruction and removal efficiency (DRE) of 99.99%. Results of testing that was conducted earlier did no show that the plasma arc reactor could fulfill this permit requirement. Four tests were conducted usir benzene as a principle organic hazardous constituent. Feed rates during the four test ranged from 0.21 gallons per minute as a minimum and a maximum of 0.580 gallons per minute. DRE from all of the tes were calculated at 99.9999% or greater.

cc: Regional Director(s), Region(s) _____12_____
      TNRCC Permit File _____HW-50259-001_____

COMPLIANCE CERTIFICATION:

GENERAL FACILITY AND TESTING INFORMATION:

1. EPA facility ID Number: TXD 982556664-1

2. Facility Name: Quantum Tech, L.L.C
   Contact Person: Prabhakar (Raja) Kulkarni
   Telephone Number: (7130-941-2823
   Facility Address: 8660 Scranton, # B
                                                   Houston, TX 77075

3. Type of Unit: Plasma Arc Reactor

4. Project Manager: 1. Larry Whicher
   Company name: Armstrong Environmental, Inc.
   Address: 4747 Irving Blvd. Suite 204
                                                      Dallas, TX 75247
                                                   2. Theodore Yen
                                                      Anacon, Inc
                                                      730 FM 1959
                                                      Houston, TX 77034

5. Date(s) of compliance test: 09/03/93-09/07/93
                                                   12/07/93-01/10/94

I certify under penalty of law that this information was prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gathered and evaluated the information and supporting plant documentation. Copies of all emission tests, and other information are available at the facility, and can be obtained from the facility contact person listed above. Based on my inquiry of the person or person's who manages the system, or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including possibility of fine and imprisonment for knowing violations.

Signature:_____   Date:_____

Title: _____

DISCLAIMER

This report is intended for the use of Quantum Tech, Inc.. The report may be subject to varying interpretations and/or may be misinterpreted by third persons or entities who were not involved in the investigative or consultation process. Quantum Tech, Inc. therefore expressly disclaims any liabilities to persons who may use this report or rely upon this report in any way or for any other purpose.

FOREWORD

This report is submitted as per the requirements of the Hazardous Waste Permit # HW-50259-001, section VIII.F.9, page 27 of 31. Test burns were carried out by Quantum Tech, Inc. in accordance with the procedures specified in the permit to verify that the Plasma Arc Reactor achieves the performance goals as specified in Provisions VIII.B.1 through VIII.B.3 of the hazardous waste permit.

PROGRAM SUMMARY

Quantum Tech, L.L.C operates a Plasma Arc Reactor under a hazardous waste permit # HW-50259-001 for disposal of hazardous wastes. Quantum Tech, L.L.C demonstrated conformance with the standards set forth in provisions VIII.F.B.1 through VIII.F.B.3 of the permit by carrying out stack testing on September 3, 1993 and September 7, 1993. The objective of the stack sampling was to determine emissions of HCL and particulate matter, and also to calculate the DRE (destruction and removal efficiency) of the system to destroy the Principal Organic Hazardous Constituent (POHC), in this case Benzene. Armstrong Environmental, Inc. was contracted to the stack sampling and to oversee the collection of exhaust gas samples. Three runs were conducted on the plasma reactor to satisfy these requirements.

It was suggested in the November 2, 1993 meeting by Mr. John Survis, Source Monitoring Division, TNRCC, that Quantum Tech, L.L.C needs to carry out three more tests to show complete destruction of the POHC at each sampling port. In response to the suggestion, Quantum Tech, L.L.C carried out four tests to show compliance. Anacon, Inc. was contracted by Quantum Tech, L.L.C to do the sampling and analysis. The tests were carried out in the presence of the personnel from Anacon, Inc. Concentration of carbon-monoxide and oxygen were monitored using the continuos emission monitoring systems.

For ease in understanding, the report is divided into two sections:

Section I: Stack Testing By Armstrong Environmental, Inc.

Section II: Field Sampling By Anacon, Inc.

PROCESS FLOW

The process flow diagram is as shown in the Figure 1 in the Appendix. The hazardous waste is pumped into the storage tank. The waste then flows under pressure to the screw furnace maintained at 800°F. This is done to convert the liquid into gaseous phase. With the help of the screw within the screw furnace the gases are pushed forward into the U-Tube maintained at 1600°F, with the help of heating elements. After passing through the U-tube the hazardous material (gas phase) is ready to enter the plasma zone. At the screw furnace water at a predetermined rate is added in order to prevent the build-up of carbon black made by the destruction of the benzene. This makes CO and H_2 and the reaction is as follows:

$$C_6H_6 + 6H_2O \longrightarrow 6CO + 9H_2$$

A nitrogen pressure of about 20 psi is applied along with the hazardous material to push the gases tangentially in the flame. The plasma arc generated by the plasma gun is at high temperatures sustaining temperatures of 10000°F to 30000°F. At such high temperatures almost all organic and inorganic compounds are split into individual components.

From the reactor chamber the gases are directed through a quench tank for cooling and then through a Sodium Hydroxide tower. From the towers the gases are directed to a particulate filter and then through the incinerator maintained at @ 1800°F. The gases are incinerated, resulting in no emissions at the stack, as evidenced by the stack testing.

The table below shows the initial start-up problems encountered during the trial-burn program from 7/21/93 through 9/7/93.

Date	Remark				Testing Lab.		Analytical Lab.	
7/21/93	Test aborted. Hazardous material flowmeter not reading the input of material in to the system.				South Western Lab.. (SWL)			
7/22/93	Incinerator Problems				SWL			
8/5/93	Incinerator Problems				SWL			
8/13/93	Incinerator Problems				SWL			
8/26/93	Plasma Shut-off				Armstrong Environmental Inc.			
9/3/93	TEST COMPLETED				AEI		APR Labs	
9/3/93	TEST COMPLETED				AEI		APR Labs	
9/7/93	TEST COMPLETED				AEI		APR Labs	
NOTE:	Previous tests had to be aborted due to faulty thermal switches in the plasma AC/DC converter. This fault was corrected by installing new switches							
	The flowmeter was replaced with a new one.							
	The temperature of the incinerator was not holding steady, which caused three tests to be aborted. This was due to a bad thermocouple which was replaced.							

SECTION I: RESULTS

SUMMARY OF EMMISSIONS TEST DATA

```
TABLE: 1
PLANT: Quantum Technology, Inc.,   Houston, TX
LOCATION: Plasma Reactor
OPERATOR: M.Taylor, L.Whicher
TEST DATE: September 3, 1993
REPETITION:                        1              2
```

	1	2
STACK GAS		
Temperature, F	241.4	241.8
Velocity, fps	6.500	6.512
Volume Flow, acfm	856.9	858.4
scfm	633.1	628.6
scfh	37987	37715
Moisture, %	2.11	2.94
CO2, %	0.0	0.0
O2, %	19.0	19.0
SAMPLE		
Start Time, hrs/min	10:17am	2:46pm
Finish Time, hrs/min	11:17am	3:46pm
Volume, scf	36.85	39.30
Isokinetic Ratio, %	100.1	107.5
PARTICULATE		
Front Half		
Sample Weight, mg	36.98	68.01
Concentration, gr/scf	0.0155	0.0294
Emissions, lbs/hr	0.084	0.144
Back Half		
Sample Weight, mg	8.988	0.0
Concentration, gr/scf	0.0038	0.0
Emissions, lbs/hr	0.020	0.0
Total Emissions, lbs/hr	0.104	0.144
CARBON MONOXIDE		
Concentration, ppm	772.8	8.69
Emissions, lbs/hr	2.134	0.024
BENZENE		
Concentration, ppm	ND	1.419
Emissions, lbs/hr	ND	0.011
HYDROGEN CHLORIDE		
Sample Weight,mg	0.413	0.335
Concentration, ppm	0.261	0.199
Emissions, lbs/hr	9.4E-4	7.1E-4

SUMMARY OF EMMISSIONS TEST DATA

TABLE: 2
PLANT: Quantum Technology, Inc., Houston, TX
LOCATION: Plasma Reactor Exhaust
OPERATOR: E.Dean
TEST DATE: September 7, 1993
REPETITION: 1

STACK GAS

Temperature, F	238.8
Velocity, fps	6.499
Volume Flow, acfm	856.6
scfm	628.7
scfh	37722
Moisture, %	3.12
CO2, %	0.0
O2, %	19.5

SAMPLE

Start Time, hrs/min	11:00am
Finish Time, hrs/min	12:00pm
Volume, scf	39.788
Isokinetic Ratio, %	108.8

PARTICULATE

Front Half

Sample Weight, mg	49.75
Concentration, gr/scf	0.019
Emissions, lbs/hr	0.104

Back Half

Sample Weight, mg	23.98
Concentration, gr/scf	0.009
Emissions, lbs/hr	0.050

Total Emissions, lbs/hr	0.154

CARBON MONOXIDE

Concentration, ppm	12.41
Emissions, lbs/hr	0.034

BENZENE

Concentration, ppm	6.7E-4
Emissions, lbs/hr	5.1E-6

HYDROGEN CHLORIDE

Sample weight, mg	0.478
Concentration, ppm	0.279
Emissions, lbs/hr	9.9E-4

PROCEDURE TO CALCULATE DRE

As per the 40 CFR part 264.343 the DRE can be calculated as follows:

$$DRE = 1 - \frac{(W_{out})}{(W_{in})} * 100\%$$

where,

W_{in} = mass feed rate of POHC* in waste stream (lbs/hr).

W_{out} = mass emission rate of same POHC present in exhaust emissions (lbs/hr).

*POHC = Principal Organic Hazardous Constituent (in this case Benzene).

CALCULATIONS

TEST # 1 - 9/3/93

As per the data from the stack testing by Armstrong Environmental, Inc. the POHC emissions were "ND" (not detected). This gives a DRE of 100% for the first test at the stack.

TEST # 2 - 9/3/93

As per the data from the stack analysis performed by Armstrong Environmental, Inc. the POHC emissions were 0.011 lbs/hr. That is 0.011 lbs benzene in the one hour duration of the test.

Total Benzene Input = 17 gallons = 0.284 gpm of benzene

One gallon of benzene = 7.33 lbs, hence for 17 gallons, 124.61 lbs.

W_{in} = 124.61 lbs/hr

W_{out} = 0.011 lbs/hr

Hence DRE = $\frac{124.61 - 0.011}{124.61} * 100\%$

= 99.9911%

TEST # 3 - 9/7/93

Total benzene input = 16 gallons @ 0.267 gpm
= 117.28 lbs of benzene

W_{in} = 117.28 lbs/hr W_{out} = 0.0000051 lbs/hr

$$DRE = \frac{117.28 - 0.0000051}{117.28} * 100\% = 99.9999\%$$

NOTE: Test results, summary of emission data, and procedures from Armstrong

Environmental, Inc. are presented in the Appendix.

" A REPORT ON PLASMA ARC TRIAL-BURN"

Submitted to
Texas Natural Resources Conservation Commission
1700 Congress Avenue
Austin, TX 78711-3087

Submitted By

QUANTUM TECH, INC.
8660 Scranton
Houston, TX 77075

SECTION II

PROGRAM SUMMARY

It was suggested in the November 2, 1993 meeting by Mr. John Survis, Source Monitoring Division, TNRCC, that Quantum Tech, L.L.C needs to carry out three more tests to show complete destruction of the POHC at each sampling port. In response to the suggestion, Quantum Tech, L.L.C carried out four tests to show compliance. Anacon, Inc. was contracted by Quantum Tech, L.L.C to do the sampling and analysis. The tests were carried out in the presence of the personnel from Anacon, Inc. The samples were collected by personnel from Anacon, Inc. using Niosh Method 1501. Concentration of carbon-monoxide and oxygen were monitored using the continuos emission monitoring systems.

SECTION II

OVERALL PROCEDURE

1. The system is pressurized to 40 Psi and then checked for leaks. This is done using soap solution and testing the fittings, valves, welds and joints.

2. Vacuum is pulled in the system to a level of 10^{-3} torr. This vacuum is held for 30 minutes and any loss of vacuum is observed. If there is no loss of vacuum it indicates a "no leak" system.

3. The incinerator, screw furnace and the U-Tube are maintained at the desired temperature (refer to figure 1).

4. Once the above units are at the required temperature, the plasma machine is turned on.

5. The vacuum is allowed to break and a pressure of 5 psi is allowed to be developed in the system.

6. Water at a predetermined rate is introduced in the system. Next, the hazardous material is introduced in the system.

7. A continuos record of temperatures, pressures, plasma amperage, flowrates are maintained.

8. Four minutes after the hazardous material is introduced in the system personnel from Anacon, Inc. collect the first sample at the location "a". Samples at location "b" and location "c" are collected after 60 minutes (refer to figure 1).

9. After the sampling the hazardous material flow is stopped. Plasma kept on for some time to ensure complete destruction.

10. Shut-off the plasma. This completes the trial-burn.

** The Process flow is the same as described in Section I.

FIELD SAMPLING & ANALYTICAL PROCEDURES

The compliance tests were successfully completed during 12/7/93 through 1/10/94. The process flow diagram (figure1) indicates the sampling ports for collection of gas samples and are in conformance with Provisions VIII.F.6, page 27 of 31 of the waste permit. The three locations are identical to the locations in Section I.

Field sampling and analysis was performed by :

Anacon, Inc.
730 FM 1959
Houston, TX 77034
Contact Person: Ms. Amy Jacobsen

The sampling protocol was as follows:

Sample A - collected 4 minutes after the introduction of POHC in to the reactor, at location 'a'.

Sample B - collected 60 minutes after the introduction of POHC in to the reactor, at location 'b'.

Sample C - collected 60 minutes after the introduction of POHC in to the reactor, at location 'c'.

The sampling was done using solid sorbent tubes under Niosh Method 1501. The flowrates and the sampling time was recorded. The person in charge of the project was Mr. Theodore Yen, Anacon, Inc. Four one hour tests were performed and the test schedule was as follows:

Test # 1 - 12/07/93

Test # 2 - 12/13/93

RESULTS

PROCEDURE TO CALCULATE DRE

As per the 40 Code of Federal Regulations (CFR) Part 264.343 the DRE can be calculated as follows:

$$DRE = 1 - \frac{(W_{out})}{(W_{in})} \times 100\%$$

where,
W_{in} = mass feed rate of POHC (benzene) in waste stream.

W_{out} = mass emission rate of same POHC present in exhaust emissions.

TEST 1: Sample A

DATA:

1. Benzene Input = 13 gallons

2. Sample Flowrate = 0.1 liter/min

3. Sampling time = 5 min

4. Benzene in sample = 377 µg/l

1 gallon of benzene = 7.33 lbs.

Hence $Mass_{in}$ = 13 gal x 7.33 lbs/gal x 454 gms/lbs = 43261.66 gms/60 min
= 721 gms/min

hence $Mass_{in}$ 5 minutes = 3605 gms.

$Mass_{out}$ = 377 µg/l x 0.1 lit/min x 5 min

= 188.5 µg = 0.0001885 gms

$$DRE = \frac{3605 - 0.0001885}{3605} \times 100\%$$

DRE = 99.99999 %

TEST 1 : Sample B

DATA:

1. Sample flowrate = 0.255 lit/min

2. Sampling time = 15 min

3. Benzene in sample = 75μg/l

4. Benzene Input = 721 gms/min x 15 min = 10815 gms

$Mass_{,out}$ = 75μg/l x 0.255 l/min x 15 min

$\qquad$ = 0.000286 gms

DRE = $\dfrac{10815 - 0.000286}{10815}$ x 100 %

DRE = 100 %

TEST 1 : Sample C

DATA:

1. Sampling Flowrate = 0.1 lit/min

2. Sampling Time = 15 min

3. Benzene in sample = 96μg/l

4. Benzene Input = 721 gms/min x 15 min = 10815 gms

$Mass_{,out}$ = 96μg/l x 0.1 lit/min x 15 min

$\qquad$ = 0.000144 gms

DRE = $\dfrac{10815 - 0.000144}{10815}$ x 100 %

DRE = 100 %

TEST 2 :

Benzene Input = 19 gallons = 19 gal x 7.33 lbs/gal x 454 gms/lbs = 63228.6 gms

Test Duration = 60 min,   hence benzene input = 1053.80 gms/min = 17.56 gms/sec

Sample A:

DATA:

1. Benzene Input = 1053.80 gms/min x 6 min = 6322 gms

2. Sample Flowrate = 0.231 lit/min

3. Sampling time = 6 min

4. Benzene in sample = 120 μg/l

$Mass_{out}$ = 120 μg/l x 0.231 l/min x 6 min

$\qquad$ = 0.000166 gms

DRE = $\dfrac{6322 - 0.000166}{6322}$ x 100 %

DRE = 100 %

Sample B:

DATA:

1. Sampling flowrate = 0.025 lit/min

2. Sampling time = 13 min. 30 sec = 810 sec

3. Benzene in sample = 206 μg/l

4. Benzene input = 17.56 gms/sec x 810 sec = 14223.6 gms

$Mass_{out}$ = 206 μg/l x 0.025 l/min x 810 sec

$\qquad$ = 0.000688 gms

DRE = $\dfrac{14223.6 - 0.000688}{14223.6}$ x 100 % = 100 %

Sample C:

DATA:

1. Sampling flowrate = 0.1 l/min

2. Sampling time = 14 min . 03 sec = 843 sec

3. Benzene in sample = 287 µg/l

4. Benzene input = 17.56 gm/sec x 843 sec = 14803.08 gm

Mass,$_{out}$ = 287 µg/l x 0.1 l/min x 843 sec

   = 0.000402 gms

DRE = $\dfrac{14803.08 - 0.000402}{14803.08}$ x 100 %

DRE = 100 %

TEST 3:

Benzene Input = 30 gallons = 30 gal x 7.33 lbs/gal x 454 gms/lbs = 99834.6 gms

Test Duration = 60 min, hence benzene input = 1663.91 gms/min = 27.73 gms/sec

Sample A:

DATA:

1. Sampling flowrate = 0.3 l/min

2. Sampling time = 5 min. 27 sec = 327 sec

3. Benzene in sample = 2050 µg/l

4. Benzene input = 27.73 gm/sec x 327 sec = 9067.71 gms

$\text{Mass},_{out}$ = 2050 µg/l x 0.3 l/min x 327 sec

$\qquad$ = 0.0033517 gms

$$DRE = \frac{9067.71 - 0.0033517}{9067.71} \times 100\%$$

DRE = 99.9999 %

Sample B:

DATA:

1. Sampling flowrate = 0.037 l/min

2. Sampling time = 14 min. 46 sec = 886 sec

3. Benzene in sample = 1620 µg/l

4. Benzene input = 27.73 gms/sec x 886 sec = 24568.78 gm

$\text{Mass},_{out}$ = 1620 µg/lit x 0.037 l/min x 886 sec

$\qquad$ = 0.000885 gms

$$DRE = \frac{24568.78 - 0.000885}{24568.78} \times 100\% = 100\%$$

Sample C:

DATA:

1. Sampling flowrate = 0.109 l/min

2. Sampling time = 18 min

3. Benzene in sample = 645 µg/l

4. Benzene input = 1663.91 gm/min x 18 min = 29950.38 gms

Mass,$_{out}$ = 645 µg/l x 0.109 l/min x 18 min

$\qquad$ = 0.0012654 gms

DRE = $\dfrac{29950.38 - 0.0012654}{29950.38}$ x 100 %

DRE = 99.99999 %

TEST 4:

Benzene Input = 35 gallons = 35 gal x 7.33 lbs/gal x 454 gms/lbs = 116473.7 gms

Test Duration = 60 min, hence benzene input = 1941.22 gm/min = 32.35 gm/sec

Sample A:

DATA:

1. Sampling flowrate = 0.390 l/min

2. Sampling time = 6 min. 29 sec = 389 sec

3. Benzene in sample = 2535 μg/l

4. Benzene input = 32.35 gm/sec x 389 sec = 12584.15 gms

$Mass_{out}$ = 2535 μg/l x 0.390 l/min x 389 sec

$\qquad$ = 0.006409 gms

DRE = $\dfrac{12584.15 - 0.006409}{12584.15}$ x 100 %

DRE = 99.9999 %

Sample B:

DATA:

1. Sampling flowrate = 0.250 l/min

2. Sampling time = 15 min

3. Benzene in sample = 1673 μg/l

4. Benzene input = 1941.22 gm/min x 15 min = 29118.3 gms

$Mass_{out}$ = 1673 μg/l x 0.250 l/min x 15 min

$\qquad$ = 0.006273 gms

DRE = $\dfrac{29118.3 - 0.006273}{29118.3}$ x 100 % = 99.9999 %

Sample C:

DATA:

1. Sampling flowrate = 0.114 l/min

2. Sampling time = 15 min

3. Benzene in sample = 520 µg/l

4. Benzene input = 1941.22 gm/min x 15 min = 29118.3 gms

$Mass_{,out}$ = 520 µg/l x 0.114 l min x 15 min

$\quad\quad$ = 0.000889 gms

DRE = $\frac{29118.3 - 0.000889}{29118.3}$ x 100 %

DRE = 100 %